Golder Associates Inc.
CONSULTING ENGINEERS

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PRE-DESIGN INVESTIGATION
TASK S-3
IDENTIFY SOURCES OF CAP MATERIALS
INTERIM FINAL REPORT

INDUSTRI-PLEX SITE
WOBURN, MASSACHUSETTS

Prepared for:

Industri-Plex Site Remedial Trust
800 North Linbergh Boulevard
St. Louis, Missouri 63167

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September 1990 Project No.: 893-6255

Golder Associates Inc.
CONSULTING ENGINEERS

September 14, 1990 Project No. 893-6255

United States Environmental Protection Agency, Region 1
Waste Management Division
J.F.K. Federal Building HRS-CAN3
Boston, Massachusetts 02203

Attn: Joseph DeCola

RE: INDUSTRI-PLEX SITE PRE-DESIGN INVESTIGATION
TASK S-3 IDENTIFY SOURCES OF CAP MATERIALS
INTERIM FINAL REPORT

Gentlemen:

On behalf of the Industri-Plex Site Remedial Trust, we are submitting the attached Cap Materials Interim Final Report for the Industri-Plex Site in Woburn, Massachusetts. This report is being submitted in accordance with the Pre-Design Investigation Work Plan (PDI) Task S-3 reporting requirements (PDI Sections 3.2.5.5 and 3.8.1.1.3, p. 50 and 127).

Please contact us if you have any questions.

Very truly yours,

GOLDER ASSOCIATES INC.

James W. Voss
Principal

KRM/krm
C:CAPCL

cc: J. Naparstek, MDEP
A. Ostrofsky, NUS
D. L. Baumgartner, ISRT
W. L. Smull, ISRT

1.0 INTRODUCTION

This report is submitted in fulfillment of the Interim Final Report deliverable for the Pre-Design Investigation (PDI) Task S-3, Identify Sources of Cap Materials, as specified in Sections 3.2.5.5 (p. 50) and 3.8.1.1.3 (p. 127) of the PDI Work Plan.

1.1 Purpose

The purpose of this interim final report is to provide the geotechnical characteristics, availability, and location of potential materials for the cap designs that will be used at the Industri-Plex Site in Woburn, Massachusetts. Two cap designs are specified in the Consent Decree. A permeable cover consisting of a geotextile overlain by clean, imported fill will be used in areas of the site where hides are present and/or the concentrations of metals (arsenic, chromium and lead) exceed action levels. An impermeable cover consisting of a flexible membrane liner to establish impermeability and control odors, with a gas collection system to collect gases will be placed on the East Hide Pile.

This interim final report discusses the background and requirements set forth in various governing documents for the sampling and testing of the cap borrow sources; the sampling and laboratory testing protocols used in the investigation; and test results, interpretations and recommendations for the potential borrow sources for the individual cap components.

1.2 Consent Decree Objectives

On April 24, 1989, a Consent Decree was entered between the Industri-Plex Site Remedial Trust (ISRT), the United States Environmental Protection Agency (USEPA), and the Massachusetts Department of Environmental Protection (MDEP), which defines the scope of the remediation at the Industri-Plex Site in Woburn, Massachusetts. The objective of the

remediation is stated in the Record of Decision (ROD), prepared by the USEPA in September 1986, page 27:

> "...the objective of the remedial alternatives addressing contaminated soils and sludges is to prevent the public from coming into direct contact with these materials."

The Consent Decree incorporates the Remedial Design/Action Plan (RDAP) which outlines various remedial requirements. As stated in the RDAP:

> (p.1) "The remedial action for soils, sediments, and sludges contaminated with Hazardous Substances, other than those emitting odors (the East Hide Pile), shall include site grading, capping with a permeable soil cover, excavation, dredging, and/or consolidation for all areas containing Hazardous Substances at concentrations above established action levels (300 ppm = arsenic, 600 ppm = lead, 1000 ppm = chromium...)"
>
> (p.7) "The remedial action shall consist of stabilizing the side slopes of the East Hide Pile, installing a gas collection layer, capping with a synthetic membrane liner to establish impermeability, and soil cover in accordance with Attachment A..."

The RDAP requires the execution of a Pre-Design Investigation (PDI) which includes the identification of potential cap material sources. Specifically, the RDAP states that :

> (p. 14) "(f) An investigation to evaluate sources of cap materials for their ability to meet technical design requirements as specified in (this) Consent Decree or otherwise approved by EPA and the Commonwealth."

This interim final report constitutes the results of the cap materials investigation, which has been conducted to meet the requirements set forth in the RDAP and PDI.

2.0 PROJECT REQUIREMENTS

2.1 General

Borrow materials are required for the two types of cover as discussed in the RDAP:

1. A permeable cover over the areas where hides are present and/or the concentrations of arsenic, chromium, and lead are at/or exceed ROD action levels.

2. A Flexible Membrane Liner (FML) cover with a gas collection system over the East Hide Pile in order to establish impermeability and control odors.

The construction of both caps require importation of soil and synthetic materials. The specific requirements for each cap and their individual components are discussed in the following sections.

2.2 Permeable Cap Requirements

A cost effective permeable cover is discussed in the Alternative Cover Design Report (ACDR) prepared by Golder Associates (Reference 5). This alternate cover design was subsequently approved by the USEPA and MDEP. Specifically, the permeable cap components as approved by USEPA and MDEP are (from bottom to top):

1. A geotextile; and
2. A 16-inch thick imported soil fill.

The factors that were considered in the selection of the alternate cap included:

- Elimination of direct contact of contaminated soils with the public;
- Effect of freeze/thaw cycle;
- Effect of erosion;

- Durability and long-term reliability, and
- Quality control during installation.

2.2.1 Geotextile

The geotextile will serve several functions. First, it will provide a visual definition of the top of the contaminated soils and provide separation between the contaminated soils and the imported borrow soil. The geotextile can be specifically included in the institutional controls for the site as a further means of reducing the chance of incidental contact through land use. Secondly, the geotextile will inhibit the upward migration of stones and construction debris from the existing soil matrix as a result of freeze/thaw. The geotextile, itself, is not subject to freeze/thaw effects and will allow water to freely move upward or downward. In addition, the geotextile can have sufficient mechanical strength and modulus to resist uplifting objects from the contaminated soils. Thirdly, it provides a continuous barrier in the event the soil cover is eroded or locally disturbed. Lastly, the geotextile discourages root penetration into contaminated soils.

The ACDR indicates several properties of the geotextile that will meet or exceed the engineering requirements and functions at the site. The geotextile shall be made of polypropylene or polyester. These materials are considered to have a high degree of biological and chemical stability as described in the ACDR. The effective opening size shall be approximately 0.2 mm (No. 70 sieve size) to minimize the potential of fine grained particles migrating between the contaminated soil and the cover soil. Puncture strength is an important property of a geotextile, particularly in relation to the vertical displacement of objects due to freeze/thaw action. The ACDR indicates that a puncture strength of 40 pounds is adequate to resist upward migration

of objects due to freeze/thaw. The ACDR recommends that a non-woven geotextile with a unit weight of 4 ounces per square yard is suitable to meet the functions required at the site.

In addition, several measures should be taken to insure a stable foundation for the geotextile. These steps include clearing and grubbing, proof rolling, excavation of, or placement of, additional fill over areas that may puncture the geotextile or cause substantial settlements.

2.2.2 Cover Soil

The permeable cap cross section approved by USEPA and MDEP requires a 16-inch thick cover soil overlying the geotextile. The cover soil has been designed to serve several functions.

First, the soil cover will function in conjunction with the geotextile as a physical barrier to prevent direct contact with contaminated soils. Secondly, it will help mitigate the impact of freeze/thaw and erosion. The depth of frost during an average winter was calculated to remain within a 16-inch cover. Regarding erosion, it was demonstrated in the ACDR that the amount of erosion in locally damaged areas of the cover is not expected to be greater than 4 inches per year, therefore any damaged areas can be repaired as part of the maintenance program.

Thirdly, the soil cover must sustain vegetation growth. This is an important factor in evaluating its durability. A vegetated surface will greatly reduce erosion and also control the effects of freeze/thaw. Lastly, the ACDR demonstrated that 12 inches of soil over the geotextile is the upper bound for root penetration and protection of the geotextile during construction. The likelihood of phytotoxicity is reduced since roots are not likely to

encounter contaminated soils. The potential for geotextile damage during construction is also minimized by placing a 16 inch layer of cover soil.

The ACDR does not specify or suggest a particular soil type or gradation for the cover. It does reference certain cover soil properties necessary to achieve the desired functions. The report specifies the cover soil shall be a mineral soil which will not breakdown or degrade in the natural environment. The cover soil shall also have the ability to support vegetative growth. The report indicates that materials suitable for growth of a vegetative cover will either have sufficient fines or would be blended with fine-grained soils. The ACDR states that it is expected the cover soil will generally have a fines content greater than 20 percent which is equal to or greater than that for the majority of the site. The use of mulch and fertilizer can also be used to enhance vegetative growth.

Strength and compressibility are not significant properties for the 16 inch cover soil, since it will not be required to withstand significant loading. In fact, it is suggested that the soil cover be placed in a single lift and spread with low ground pressure equipment in order to minimize disturbance to the underlying geotextile. It would also be difficult for rapid and persistent vegetative growth to take place on a compacted surface.

Strength, compressibility and compaction are of importance in areas where a significant thickness of fill will be required during regrading operations. Strength and compressibility requirements are dependant on the type of land use (i.e., roads, parking lots, open areas). In these areas, all fill layers, except the uppermost, shall be placed and compacted

in controlled engineered lifts consistent with the future land use of a particular area.

2.2.3 Quantity Estimate

The ACDR indicates that an area of approximately 43 acres of the Industri-Plex Site was delineated as having hide residues and/or constituents in the upper 2 feet of soil that exceeded the action levels for arsenic, chromium, and lead. It is important to note that this area is based on sampling conducted during the Remedial Investigation (RI). The delineation of the permeable cap limits is currently being refined based on subsequent sampling conducted by Golder in accordance with the PDI Task S-1 objectives.

Based on the best available information (43 acres), the volume of imported borrow required for the cover soil is estimated to be on the order of 93,000 cubic yards for the 16 inch layer, with 208,000 square yards of geotextile.

These estimated quantities will require adjustment based on the final cap limits, design grading and drainage patterns. Furthermore, the amount of geotextile will need to be calculated including overlap and waste. This can best be estimated when individual roll dimensions are available.

2.3 Impermeable Cap Requirements

The RDAP specifies an impermeable cap will be placed over the East Hide Pile in order to mitigate odors and collect gases to be treated. The impermeable cap will include (from bottom to top):

1. A gas collection layer;
2. A bedding layer;
3. An impermeable synthetic geomembrane;
4. A middle drainage layer; and,

5. A vegetated top layer.

The RDAP divides the cap components into three layers; a bottom impermeable layer consisting of the gas collection layer, bedding layer, and geomembrane; a middle drainage layer; and a vegetated top layer. The following sections will discuss the functions and requirements of the three cap layers.

2.3.1 Impermeable Layer

The bottom impermeable layer shall consist of the following in accordance with Attachment A of the RDAP:

1. A gas collection layer;
2. A bedding layer designed to prevent clogging of the underlying gas collection layer, and provide a stable base for overlying layers. The gas collection layer can also function as the bedding layer, provided it will support the weight of the cap and not abrade the overlying geomembrane;
3. An impermeable synthetic membrane having a minimum thickness of 40 mil; and,
4. A final grade of at least 2 percent.

The purpose of the gas collection system is to collect and convey the gas generated from the East Hide Pile through a network of piping to the temporary gas treatment system. The Remedial Design Work Plan (Reference 7) indicates that the piping shall be 6 inches in diameter and imbedded in gravel. The gravel will allow gas to flow to the piping system. The thickness of gravel is not specifically mentioned in any document, however, the ROD indicates a gravel layer 12 inches thick in Figure 12. It is anticipated that the gravel layer would be a minimum of 12 inches thick to allow for sufficient coverage around the piping system.

One of the most important properties for a gas collection layer is its absolute permeability (generally expressed in cm^2), that depends exclusively on the properties of the porous media and measures the flow capacity of any fluid through that media. When applied to a specific fluid, a coefficient of permeability (generally expressed in cm/sec) is defined, which also depends on the fluid properties. In the case of liquid fluids, the coefficient of permeability is generally called hydraulic conductivity. Hydraulic conductivity values determined for one fluid allow the hydraulic conductivity for any other fluid to be calculated.

For the borrow areas potentially usable for the gas collection layer in this project, hydraulic conductivity tests have been conducted on samples using distilled water, as an indirect measurement of their flow capacity, and from which hydraulic conductivity values could be determined for other fluids during the design stage. Since no specification of absolute permeability or hydraulic conductivity has been given in any of the governing documents, a hydraulic conductivity of 1.0×10^{-3} cm/sec is proposed as the minimum required for this layer.

As stated in the RDAP, the function of the bedding layer is to prevent clogging of the underlying gas collection system and provide a stable base for overlying layers. Since a geomembrane overlies the bedding layer, its function to prevent clogging is redundant. Also, the load from overlying layers is minimal and the gas collection system could also function as the bedding layer. Therefore, the need for a bedding layer will be re-evaluated as part of the design.

The property of importance for the bedding layer is the gradation and texture of the particles. A coarse and angular bedding layer may abrade and imbed into the overlying geomembrane, compromising its integrity. Also, a bedding layer that has a finer particle size distribution than the gas collection layer may migrate downward and clog the gas collection layer. As suggested in the Remedial Design Work Plan (p. 23) it may be advantageous to use a geotextile directly on top of the bedding layer to provide a cushion and clean working surface for the placement of the geomembrane. If the bedding layer contains finer particles than the underlying gravel, the use of a geotextile between the bedding layer and the gas collection layer would prevent particle migration downward.

A geomembrane having a minimal thickness of 40 mil is required by the RDAP to be placed on top of the bedding layer. The function of the geomembrane is to establish impermeability to prevent the migration of gases to the air and percolation of water into the East Hide Pile. No material type is specified. The choice for a geomembrane is basically related to its durability, strength, and constructability. The durability of a geomembrane is related to its chemical, physical, and mechanical properties. The mechanical properties are related, in part, to the sheet thickness. Strength properties and survivability are increased with a thicker sheet.

High density polyethylene (HDPE) is widely used for landfill liners and closures, because it is more resistant to most chemical substances than other geomembrane polymers (Reference 8). HDPE is also a low cost material relative to other liner options.

Considering the advantages discussed above, as well as Golder's experience, HDPE is tentatively recommended as the impermeable layer component. There are various properties of importance for HDPE including thickness, strength, and puncture resistance. The minimum standards for HDPE flexible membrane liner are outlined in the National Sanitation Foundation (NSF) Standard Number 54 (Reference 9). Typically thicknesses for HDPE liners are 40 or 60 mils. Generally, field testing allows for a variance in thickness of 10 percent. The minimum strength requirements for 40 and 60 mil HDPE are listed below:

	40 mil	60 mil
Tensile Strength at Yield (lb/in. width)	70	120
Tensile Strength at Break (lb/in. width)	120	180
Elongation at Yield (Percent)	10	10
Elongation at Break (Percent)	500	500

The NSF does not give minimum requirements for puncture resistance. Typically landfill liner specifications for geomembranes require puncture resistance of 40 and 60 pounds for 40 and 60 mil HDPE, respectively.

2.3.2 Middle Drainage Layer

A drainage layer is required to be placed on top of the geomembrane. The RDAP specifies in Attachment A that the middle drainage layer shall be:

"(1) of a thickness designed to accommodate the expected amount of settling and the maximum volume of water that could enter the drainage layer, but in any event no less than 6 (six) inches;

(2) consisting of a material whose permeability exceeds 1×10^{-3} cm/sec., i.e., a sand in the SW or SP range of the Unified Soil Classification System or coarser material;

(3) designed and constructed with a bottom slope of at least 2 percent; and,

(4) designed and constructed to prevent clogging."

The function of the drainage layer is to transmit the maximum volume of water that could enter the system to prevent ponding effects. The significant properties of the drainage layer are gradation and hydraulic conductivity as specified by the RDAP. The gradation of the drainage layer is important since it is related to permeability. The angularity is also important for the survivability of the underlying geomembrane, to minimize abrasions and scratches during installation.

The thickness of the drainage layer will depend on design calculations. The RDAP specifies a thickness of no less than 6 inches. It must be considered that the thickness of cover over the geomembrane should be, at a minimum, equal to the depth of frost penetration to allow for a functioning drainage layer throughout the year. The ACDR indicated that the average frost depth will not penetrate a 16 inch cover.

2.3.3 Vegetated Top Layer

A vegetated layer is required to be placed above the drainage layer. The RDAP in Attachment A specifies the vegetated top layer shall be:

"(1) of a thickness designed to accommodate the maximum depth of root penetration and the rate of anticipated soil loss, but in any event no less than 6 inches;

(2) capable of supporting vegetation that minimizes erosion and minimizes continued maintenance;

(3) planted with a persistent species with roots that will not penetrate beyond the vegetative and drainage layers;

(4) designed and constructed with a top slope of between three (3) percent and five (5) percent after settling and subsidence or, if designed and constructed with a slope of greater than five (5) percent, an expected soil loss of less than two (2) tons/acre/year using the USDA universal soil loss equation; and,

(5) designed and constructed with a surface drainage system capable of conducting effective run-off across the cap."

The functions and requirements of the upper vegetated layer are well outlined above. The properties relative to these functions include gradation, organic content and soil fertility. These properties are important to properly design a consistent seed and fertilizer program for rapid and persistent vegetative growth.

2.3.4 Quantity Estimate

Quantity estimates for the various impermeable cap components are given in the Pre-Design Work Plan (p. 48) and are discussed below. The estimates are based on a cap size of approximately 3.8 acres and the minimum thicknesses specified in the RDAP. The quantities are subject to change based on the final cap design and dimensions.

The quantity of gas collection gravel required will be on the order of 6,000 cubic yards, based on a 12-inch thick layer.

The amount of geomembrane required is 3.8 acres or about 18,400 square yards. This estimate does not account for overlap and waste, that can be calculated when the individual roll dimensions are available.

The amount of material for the middle drainage layer is estimated to be 3,000 cubic yards, based on the minimum thickness of 6 inches.

The total volume required for the vegetated top layer is approximately 6,000 cubic yards, based on a thickness of 12 inches over the 3.8 acre area. This thickness is consistent with that given in the ACDR as the upper bound for supporting vegetation and root penetration.

As discussed before, a bedding layer may not be required. In case it is included in the design, the required volume would be 3,000 cubic yards, based on a minimum thickness of 6 inches. Additionally, one or two geotextile layers may be included over the 3.8 acre area (18,400 square yards per layer).

3.0 POTENTIAL BORROW SOURCES

3.1 Soils

Golder contacted 15 local suppliers in the Boston area and inquired about the availability of borrow soils. The suppliers were asked to potentially supply the following volumes of borrow soils:

93,000 cubic yards fill
6,000 cubic yards topsoil
6,000 cubic yards gravel
3,000 cubic yards sand

The topsoil borrow investigated corresponds to mineral soil materials containing organic matter, that were removed from the upper soil horizons during clearing and grubbing operations at other sites, and stockpiled for future sale. This material is the most appropriate to constitute the vegetated top layer of the covers, since its origin is precisely that. Although other alternatives are possible for the vegetated top layer (mix of other materials, for example) it was preferred to investigate topsoil sources because it is readily available in the area and it would require the least treatment to support vegetative growth.

Four of the fifteen suppliers indicated that they were interested in providing the required borrow quantities. They are:

Reddish Hauling, Inc.
North Plymouth, Massachusetts

Joseph Roberto, Inc.
Burlington, Massachusetts

E.H. Perkins Construction
Wayland, Massachusetts

Townsend Sand and Gravel
Townsend, Massachusetts

These suppliers were asked to identify borrow source locations. They indicated that borrow locations are available within the towns of Plymouth, Canton, Middleboro, Sterling, Hudson, Gardner, Taunton, Berkley, Townsend, Burlington, Winchendon, Billerica, Hubbardston, and Ashburnham, Massachusetts.

Golder visited borrow pits owned or operated by Joseph Roberto, Inc. and E.H. Perkins Construction. The Townsend Sand and Gravel location was one of the sites visited with Joseph Roberto, Inc. Reddish Hauling, Inc. sources were not visited due to their distance and location south of Boston. A total of five locations were visited with Joseph Roberto, Inc. These included borrow pits in Townsend, Ashburnham, Winchendon, Hubbardston, and Billerica, Massachusetts. Two sites were visited with E.H. Perkins Construction. These included the Kane Perkins site in Hudson and the Quinn Perkins site in Burlington, Massachusetts. The approximate locations of these sites are illustrated in Figure 1. Photographs of each of the sites are included in Figures 2 through 8.

The borrow sources were sampled on May 4, 1990 and July 18, 1990 by Golder personnel. Generally, the samples were taken from either a stockpile or a cut-face. A reconnaissance was made of the site to verify, by visual inspection, the homogeneity and types of soils present. Representative samples were typically collected at a 1-foot depth and placed in 5-gallon buckets or sample bags for transport to Golder Associates laboratory. The number of samples required of the soil components of the caps is defined in Table 6 of the Pre-Design Work Plan and is reproduced in Table 1 of this report, together with the number of samples collected. Table 2 indicates the potential use of the samples.

The following is a brief summary of each site from observations and discussions with representatives of Joseph Roberto and E.H. Perkins:

Townsend: One sample of sand (two 5-gallon buckets) was taken from the site. The site is relatively flat with few stockpiles. The soil is predominantly sand with varying amounts of gravel. The site is approximately 25 acres in size.

Ashburnham: One sample of sand (2 sample bags) was taken from the site. The site has extensive highwall cuts exposed. The soil is a medium to fine sand, relatively homogeneous, with a few fine sand lenses. The site is on the order of 85 acres in size.

Winchendon: One sample of sand (2 sample bags) was taken from a working face. The site has been in operation periodically for about 2 years. It is estimated that approximately 25,000 to 50,000 cubic yards of sand are available. The sand is medium to coarse and appears relatively homogeneous with a few silt and fine sand lenses. The top 2 feet to 4 feet of the cuts observed were mostly gravel and cobbles.

Hubbardston: One sample of sand (2 sample bags) was taken from an unscreened stockpile. One sample of sand mixed with gravel (2 sample bags) was taken from a screened stockpile. One sample of topsoil was taken from a stockpile. The site is approximately 151 acres in size and has been in operation since the early 1960's. It is estimated that the site has about 21 million cubic yards of reserve. The site does have a screening operation. The topsoil stockpile was noted to be limited and contained branches and cobbles that would require screening.

Billerica: One topsoil sample (2 sample bags) was taken from a stockpile. The topsoil is stockpiled from various locations in Massachusetts and southern New Hampshire. It is estimated that approximately 20,000 cubic yards are available.

Kane Perkins: Samples of screened and unscreened topsoil were collected. The site is approximately 200 to 300 acres consisting of a concrete and processing plant. The topsoil is taken from farmland in the area which is being developed. Approximately 30,000 to 40,000 cubic yards of screened and unscreened topsoil is available.

Quinn Perkins: Two samples of 3/8-inch stone and one sample of 3/4-inch stone were collected. In addition, two samples of fill (concrete sand and prepared gravel) were taken. The site serves as a processing plant that receives material from six different sites. Each site is approximately 200 to 300 acres with a combined reserve on the order of 5 million cubic yards.

The Townsend site is located northwest of Woburn approximately 55 miles. The truck route would involve travelling 495 North to 93 South to 128 South. The Ashburnham, Hubbardston and Winchendon sites are located approximately 65 to 70 miles west of Woburn. The truck route from these sites would be via Route 2 East to 495 North to 93 South to 128 South. The Billerica site is located approximately 10 to 15 miles northwest of Woburn. The route from the site would involve travelling Route 3 South to Route 128 North. The Quinn Perkins site is located approximately 4 miles off Route 128 South of Woburn. The Kane Perkins site is located in Hudson about 30 miles west of Woburn. The truck route from Hudson would be via Route 30 East to Route 128 North.

It is understood that MDEP permitting addresses the environmental sensitivity of borrow pits; hence, these permitted borrow sources should not be environmentally sensitive areas. Additional sources may be determined by the selected contractor prior to actual cap construction. These additional sources would need to be investigated to assure that the design specifications are met. Materials specifications, sampling and testing protocols, and approval procedures shall be specified as part of the bid documents

that will be prepared in accordance with the Remedial Design Work Plan.

3.2 Geosynthetics

Golder visited the Geosynthetics Research Institute (GRI) at Drexel University in Philadelphia, Pennsylvania and developed a list of major geotextile and geomembrane manufacturers. The major geotextile manufacturers include:

Amoco Fabrics and Fibers Company
Atlanta, Georgia

Hoechst Fibers Industries
Spartansburg, South Carolina

Mirafi, Inc.
Charlotte, North Carolina

Phillips 66 Company
Pasadena, Texas

Polyfelt, Inc.
Evergreen, Alabama

Reemay, Inc. (formerly DuPont)
Old Hickory, Tennessee

The major geomembrane manufacturers include:

Gundle Lining Systems, Inc.
Houston, Texas

National Seal Company
Palatine, Illinois

Poly-America Inc.
Grand Prairie, Texas

Schlegel Lining Technology
Houston, Texas

Three manufactures of each type of geosynthetic were contacted. The three geotextile manufacturers included Hoechst Fabrics which produces Trevira products, Amoco, and Polyfelt. The three geomembrane manufacturers included Gundle, National Seal, and Schlegel. Each manufacturer was requested to send representative samples of 4-ounce/yard non-woven polyester or polypropylene geotextile and 40 mil thick HDPE geomembrane to Golder's Environmental Construction Services Laboratory in Atlanta, Georgia. The specific products received included:

Amoco	4504
Hoechst Fabrics	Trevira 1114
Polyfelt	TS500
Gundle	Gundline HD
National Seal	Enviroseal HDPE
Schlegel	SLT Hyperflex

Schlegel does not produce 40 mil HDPE so their 60 mil product was tested as a substitute. The product information for these materials is included in Appendix A.

4.0 LABORATORY TESTING

A comprehensive laboratory testing program was conducted to evaluate the geotechnical properties of the selected soils and geosynthetics. The testing program was designed to meet the objectives set forth in Table 6 of the Pre-Design Work Plan and the requirements outlined in the Data Quality Objectives (DQO) included as Table 16 of the Pre-Design Work Plan; these two tables are reproduced in Appendix D. Tables 1 and 2 compare the testing program conducted with the requirements of the DQO and the PDI Work Plan. The following sections discuss the methodology and samples tested for the soils and geosynthetics.

4.1 Soils Testing

Soils testing was conducted at Golder Associates Geotechnical Laboratory in Mt. Laurel, New Jersey. Laboratory testing was performed on samples collected from selected borrow sources discussed in Section 3.1. The testing program was conducted to determine the geotechnical properties of the soil samples from borrow sources that could be used to obtain fill, gas collection layer material (gravel), drainage layer material (sand), and topsoil.

The number of tests performed met or exceeded the requirements in the Pre-Design Work Plan as explained below. The test types to be conducted on each soil sample were selected after considering its potential function as a component of the impermeable and permeable cover designs. Some of the samples can potentially meet the requirements and functions of more than one of the cap components. For instance, many of the samples could function as the sand drainage layer and also as general fill. Thus, permeability and Proctor tests were also conducted on these samples. Table 2 summarizes the testing conducted on the soil samples for the individual cap components.

The following narrative discusses the types of tests conducted, methodology and samples tested.

1. Moisture content was determined on all samples. A total of 15 moisture tests were conducted. The samples were tested in accordance with American Society for Testing and Materials (ASTM) Standard D2217-85.

2. Mechanical grain size distribution tests were conducted on a total of 15 samples. Additional hydrometer tests were conducted on those samples containing a significant amount of fines; a total of 7 hydrometer tests were conducted. The tests were performed in accordance with ASTM Standards D421, D422, and C136.

3. Atterberg limits (plastic and liquid limits) were conducted on a total of 13 samples. These tests were not performed on the two Quinn Perkins gravel samples that are obviously non-plastic. The tests were performed in accordance with ASTM Standard D4318-84.

4. Specific gravity was generally determined on those samples for which Modified Proctor and/or consolidation tests were conducted. A total of 9 tests were run including 7 sand samples and 2 topsoil samples. These tests were conducted in accordance with ASTM Standard D854-83.

5. Maximum and minimum density values of the two Quinn Perkins gravel samples and Hubbardston sand samples were determined. The tests were performed as an alternative for the Modified Proctor tests due to the absence of fines and the coarse nature of the samples. The tests were performed in accordance with ASTM Standards D4254 and D4253.

6. Modified Proctor tests were conducted on all sand samples to establish moisture/density relationships. These samples are regarded as having the greatest potential for use as general fill in areas requiring extensive lifts. A total of 7 tests were conducted. The tests were performed according to ASTM Standard D1557.

7. Rigid wall permeability tests were conducted on all sand and gravel samples for potential use as the sand drainage and gas collection components. A total of 9 tests were conducted. The tests were conducted in accordance with Army Corps of Engineers EM-111-2-1906, Appendix 7 (with recent updates).

8. Four potential fill samples were chosen to conduct consolidated undrained (CU) triaxial strength tests with pore pressure measurement. The samples were generally compacted to 95 percent of the maximum dry density and tested with 3, 6, and 9 pounds per square inch (psi) confining pressures. The tests were conducted in accordance with Army Corps of Engineers EM-1110-2-1906, Appendix 10 (with recent updates).

9. Consolidation tests were conducted on four potential fill samples. The tests were run on the same samples as the strength tests. The tests were performed in accordance with ASTM Standard D2435-80.

10. Soil pH was determined for all sand and topsoil samples to evaluate, in part, the potential for vegetative growth. The pH test was not conducted on the Quinn Perkins gravel samples or the combined Kane Perkins unscreened topsoil. A total of 12 tests were performed. Five of the tests (on topsoil samples) were conducted by the Pennsylvania State University. The remaining tests were performed by Golder using ASTM Standard G51-77.

11. The organic content was calculated on the same samples as soil pH. The test was performed in accordance with ASTM Standard D2974.

12. Baker tests, developed at the Pennsylvania State University to determine growth potential and fertility, were conducted on five topsoil samples. These tests were conducted by the Pennsylvania State University.

The soil properties determined in these tests are discussed in Sections 5.1.1 and 5.1.2.

4.2 Geosynthetics Testing

Geosynthetics laboratory testing was conducted at Golder Associates Environmental Construction Services Laboratory in Atlanta, Georgia. Samples were forwarded from selected manufacturers to the laboratory. The testing program was conducted to verify manufacturers published properties for materials that could be used in the permeable and impermeable caps. The number of tests performed meets the requirements outlined in the Pre-Design Work Plan. Additionally, for the geotextiles, the puncture resistance test was also conducted.

The following narrative discusses the types of tests conducted, their methodology, and the samples of geotextile and geomembrane tested.

Geotextile

1. The mass per unit area (commonly referred to as weight) was determined for all three of the geotextile samples. The results are reported in ounces per square yard (oz/yd^2). The test was performed in accordance with ASTM Standard D3776.

2. The apparent opening size (AOS) or equivalent opening size (EOS) test was conducted on all three geotextiles. The results are reported as the equivalent U.S. Standard sieve size or the sieve size in millimeters. The tests were conducted in accordance with ASTM Standard D4751.

3. The DQO does not require the puncture resistance test to be conducted on geotextiles. However, the test was performed on all three geotextile samples since its importance is indicated in the ACDR. The tests were run in accordance with ASTM Standard D4833.

Geomembrane

1. Thickness was determined for all three geomembrane samples. The thickness is reported in mils. The tests were conducted in accordance with ASTM Standard D374.

2. Puncture resistance tests were conducted on all three geomembrane samples. The tests were conducted in accordance with the Federal Test Method Standard (FTMS) No. 101C.

3. Tensile strength tests were conducted on all three geomembrane samples. The strength at yield and at break were measured in pounds per inch. The elongation at yield and at break were also measured and reported as a percentage. The strength and elongation were calculated in the machine direction (MD) and the transverse direction (TD) of the geomembrane sheet. The test was conducted in accordance with ASTM Standard D638.

5.0 GEOTECHNICAL TEST RESULTS

The following sections discuss the results of the geotechnical laboratory testing on the potential borrow soil and geosynthetic sources.

5.1 Soils

Laboratory test results for potential borrow sources are summarized in Table 3. The discussion of results has been subdivided into sand and gravel, and topsoil.

5.1.1 Sand and Gravel

The index properties (Atterberg Limits and particle size distribution) indicate the soils tested are characteristically non-plastic (NP) and are predominantly sands or gravels with varying amounts of silt content. The fines content ranged from 0.3 percent for Townsend Sand and Quinn Perkins 3/8 inch gravel to 12.6 percent for Winchendon Sand. Generally, the soils are classified as a poorly graded sand or gravel (SP or GP) using the Unified Soils Classification System (USCS), and sand to extremely gravelly sand under the United States Department of Agriculture (USDA) system. The USCS and USDA classifications are indicated on the grain size distribution curves in Appendix B. The Atterberg limits results are also included on the grain size distribution sheets.

Specific gravity results ranged from 2.70 for Ashburnham Sand to 2.85 for Quinn Perkins Concrete Sand. The grain size distribution curves include the specific gravity results.

Modified Proctor compaction tests were conducted on sand samples. The moisture/density relationships are presented in Appendix B. The maximum dry density values ranged from 103.0 for Quinn Perkins prepared gravel to 129.0 pounds per cubic foot (pcf) for Winchendon sand. Optimum moisture contents

ranged from 6.0 to 15.0 percent for Hubbardston Sand and Winchendon Sand, respectively. The moisture/density curves include degree of saturation lines based on the specific gravity of the soils. The maximum and minimum density of the Quinn Perkins gravel samples were determined. The minimum dry density for the 3/8 inch stone was found to be 89.1 pcf and the maximum dry density was 106.4 pcf. The minimum and maximum dry density values for the 3/4 inch stone were found to be 79.5 and 100.7 pcf, respectively.

The permeability values on sand samples range from 2.3×10^{-2} centimeters per second (cm/sec) for Ashburnham Sand to 5.8×10^{-4} cm/sec for Quinn Perkins Prepared Gravel. The permeability tests for the Quinn Perkins 3/8 and 3/4-inch gravel indicate values of 1.6×10^{-2} and 3.6×10^{-2} cm/sec, respectively.

Total and effective stress Mohr's circles determined in the triaxial tests are presented in Appendix B. Friction angles were calculated for effective stress conditions and are presented with the Mohr's Circles. These friction angles range from 33.4 to 39.8 degrees. The results of the consolidation tests are also presented in Appendix B. The compression index (C_c) determined for the consolidation tests ranges from 0.042 to 0.114.

The organic content and soil pH results are presented on Table 3. The organic content for sand samples ranged from 0.3 percent for the Quinn Perkins Concrete Sand to 0.86 percent for Quinn Perkins Prepared Gravel. Soil pH values range from 4.5 to 5.8 on the Hubbardston and Winchendon Sands, respectively.

5.1.2 Topsoil

The index properties indicate the soils tested are characteristically non-plastic (NP) and are predominantly sand with varying amounts of silt. The fines content ranged from 23.2 percent for Kane Perkins Unscreened (1) Loam to 32.7 percent for Kane Perkins Screened Loam. The samples are generally classified as a sand with some silt (SM) under the USCS system and gravelly to extremely gravelly sandy loam using the USDA system. The USCS and USDA classifications are indicated on the grain size distribution curves in Appendix B. The Atterberg limits are also presented on the grain size distribution sheets.

Specific gravity tests conducted on the Billerica and Hubbardston Topsoil samples yielded values of 2.63 and 2.66, respectively. These values are included on the grain size distribution curves.

The organic content ranged from 3.6 to 8.2 percent for the Hubbardston and Kane Perkins Screened Topsoil samples, respectively. The pH for topsoil samples ranged from 5.7 for Kane Perkins Screened Topsoil to 6.2 for Kane Perkins unscreened topsoil (1 and 2). Baker tests were also conducted on the topsoil samples, and show that the topsoil samples tested are adequate to support vegetation growth with the appropriate addition of fertilizer and limestone. The results of the Baker tests are presented in Appendix B, with recommendations for fertilizer and limestone.

5.2 Geosynthetics

The laboratory test results for the geotextile and geomembrane samples are included in Appendix C; a summary table for both geosynthetics and individual data sheets for the samples are included. The product information for the geosynthetics can be found in Appendix A.

The geotextiles were tested for mass per unit area, puncture strength and apparent opening size (AOS). The mass per unit area ranged from 4.0 oz/sq. yd. for Amoco 4504 to 5.0 oz/sq. yd. for Trevira 1114. The puncture strength values ranged from 80.3 pounds for Polyfelt TS500 to 100.1 pounds for Amoco 4504. The AOS values ranged from 0.174 mm for Amoco 4504 to 0.212 mm for both Trevira 1114 and Polyfelt TS500. The laboratory results for the individual samples meet or exceed the typical values reported in the product information for the respective manufacturers.

The geomembrane samples from Gundle (40 mil), National Seal (40 mil) and Schlegel (60 mil) were tested for thickness, strength and puncture resistance. The average thickness of the Gundle and Schlegel samples was significantly higher than the minimum requirement; the average thickness of the 40 mil Gundle sheet was 53.1 mils and the average thickness of the 60 mil Schlegel sheet was 75.3 mils. The strength test results are summarized in Appendix C. The strength at yield and break, and elongation at yield and break are reported for both machine direction (MD) and transverse direction (TD). The puncture resistance values ranged from 56.0 pounds for National Seal to 110.0 pounds for the Schlegel sheet.

Generally, the values reported from the laboratory meet or exceed the typical values reported in the manufactures product information. However, all three products did not meet the typical values for elongation at yield. The strength results from the laboratory testing for all three products substantially meet the minimum requirements of NSF 54.

6.0 DISCUSSION AND CONCLUSIONS

6.1 Soils

The following discussion compares the laboratory test results with the requirements and functions of the individual cap components.

The most important function of the 16 inch cover soil component of the permeable cap is its ability to support vegetative growth. Some alternatives to the use of topsoil could be considered for the vegetated top layer (permeable and impermeable caps), since its purpose is exclusively to support vegetative growth. Blends of topsoil with sand, or gravel plant silt with sand loam could be designed. This would require tilling or discing in clean areas of the site, as well as laboratory testing to design the mixes and verify that the desired mixes are achieved during construction. As mentioned in Section 3.1, the investigation of topsoil sources has been preferred because this material is the most appropriate to support vegetative growth, requires the least treatment and control during construction, and is readily available in the area.

The fertility tests on the topsoil samples do not indicate any deficiencies or toxicities to plants. In addition, the index properties show the percentage of fines is consistent with the recommendations in the Alternate Cover Design Report. The sand and gravel samples have trace or little fines, relatively low pH and a small percentage of organics; fertility tests have not been conducted, because it was evident that the sand and gravel samples would not be appropriate to sustain the vegetative growth desired.

Several options may be considered for the cover soil. In areas where only the minimum cover thickness of 16 inches is required, topsoil or alternative mixes could be used for the entire thickness of the cover soil. Combination layers of sand and topsoil could also be used; for instance, the top 6 inches may be topsoil or alternative mixes, with the remaining 10 inches sand. In areas where a substantial thickness of fill is required for regrading in low areas, topsoil or alternate mixes should be used only for the top 16 inches; sand fill should be used for the lower lifts and should be placed and compacted in controlled engineered lifts.

The results of the laboratory tests on the topsoil samples investigated indicate that they are suitable for the top vegetated layer of the impermeable cap.

The specific requirements for the middle drainage layer of the impermeable cap involve material gradation and permeability. All sand samples, except the Winchendon Sand, meet the gradation requirements. All sand samples met the minimum hydraulic conductivity value of 1×10^{-3} cm/sec. The Quinn Perkins prepared gravel did not meet the required permeability or gradation.

The preliminary requirement of a uniformly graded gravel (GP) for the gas collection system is met by the Quinn Perkins 3/8" and 3/4" gravels. Both samples are sub-rounded to sub-angular, have only a trace of fines and relatively high hydraulic conductivity values.

The laboratory testing program conducted on the soil samples should be considered as preliminary and should be used as an initial evaluation of potential sites for borrow sources. The samples obtained from each site were taken from stockpiles or cut-faces. It is unlikely that these stockpiles and working faces will still exist at the time of construction. It is also likely that development and construction in the site area may produce the quantities and types of soils needed, and consideration should be given to other potential borrow sources. In any event, additional sampling and testing of the borrow materials to be used will be required prior to construction. Once a site is chosen, a sampling and testing program will be required at a specified frequency to verify soil properties as borrow excavation progresses (see Section 7.0).

6.2 Geosynthetics

Three samples of geotextile and geomembrane were tested for the properties specified in the PDI Work Plan. The results of the geotextile testing were compared to the requirements and functions set forth in the Alternate Cover Design Report. All three geotextiles, Amoco, Trevira, and Polyfelt meet these requirements. The results of the geomembrane tests were compared with the NSF 54 standards. All three geomembranes, from Gundle, National Seal, and Schlegel meet the minimum standards.

The choice of geosynthetics appears to be one of experience and cost. The test results should be regarded as preliminary. Conformance testing will be needed at a specified frequency for the actual materials used in the field. Material specifications, sampling and testing frequencies, and approval procedures shall be specified as part of the bid documents that will be prepared in accordance with the Remedial Design Work Plan (see Section 7.0).

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(continued)

7.0 PROPOSED CONFORMANCE TESTING

The borrow source study presented in this report should be considered as preliminary and intended only to verify the existence of sufficient and appropriate borrow materials in the site vicinity. At the time of construction, contractors will select the soil borrow areas and geosynthetic manufacturers they propose to use and submit testing information for initial approval. During construction, conformance testing of the actual materials should be conducted to verify material properties. Some alternatives to the materials discussed in this report could also be considered during the final design process.

The final quality requirements for all materials, the sampling and testing protocols, and the approval procedures will be specified as part of the bid documents to be provided to the potential contractors in accordance with the Remedial Design Work Plan.

C:CAPMAT

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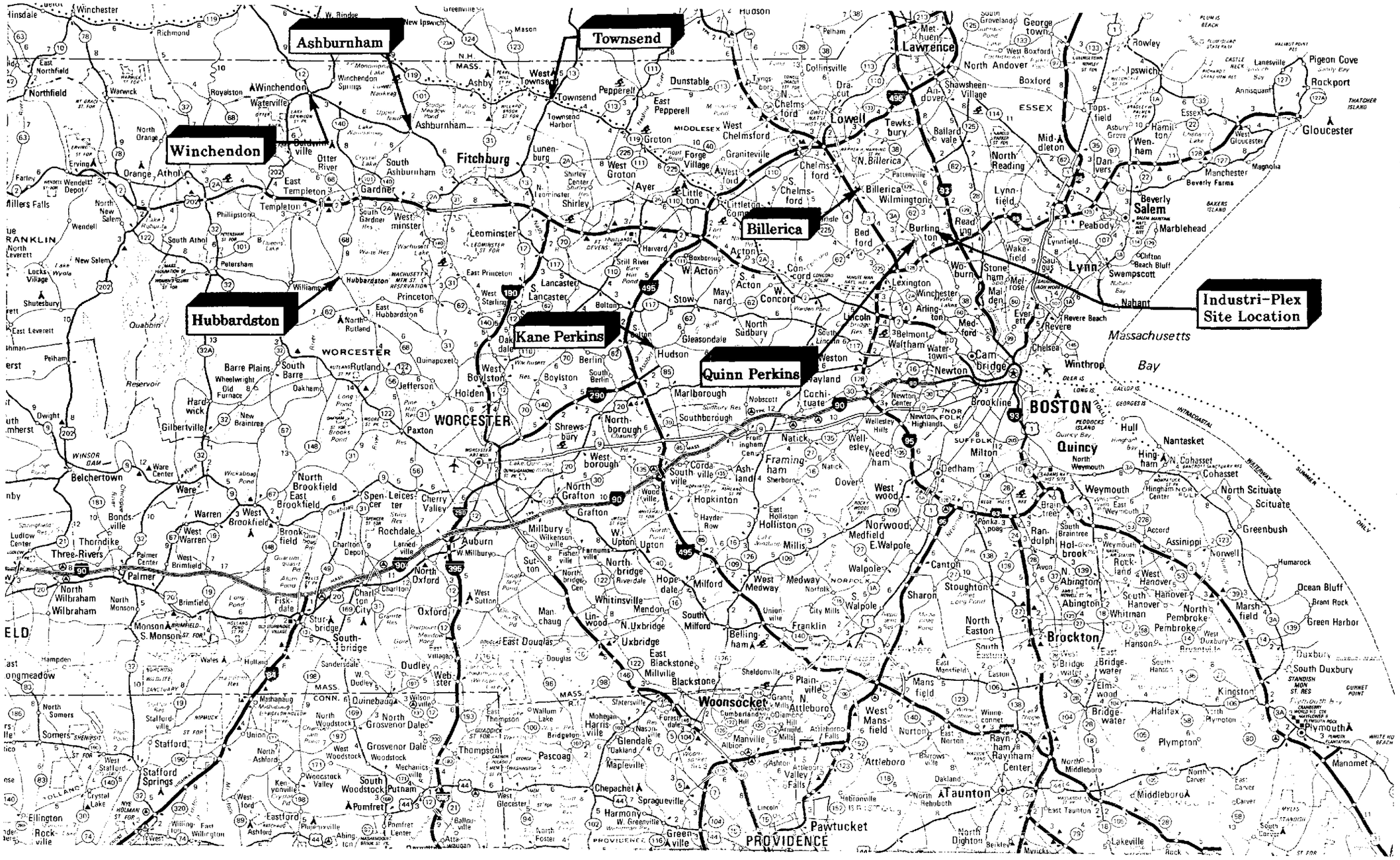
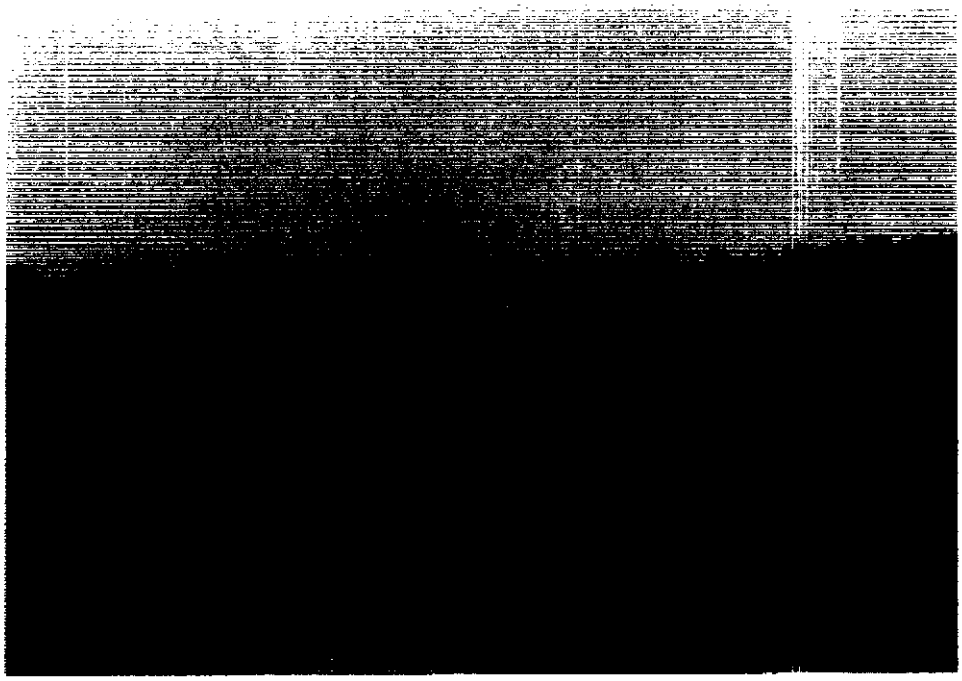


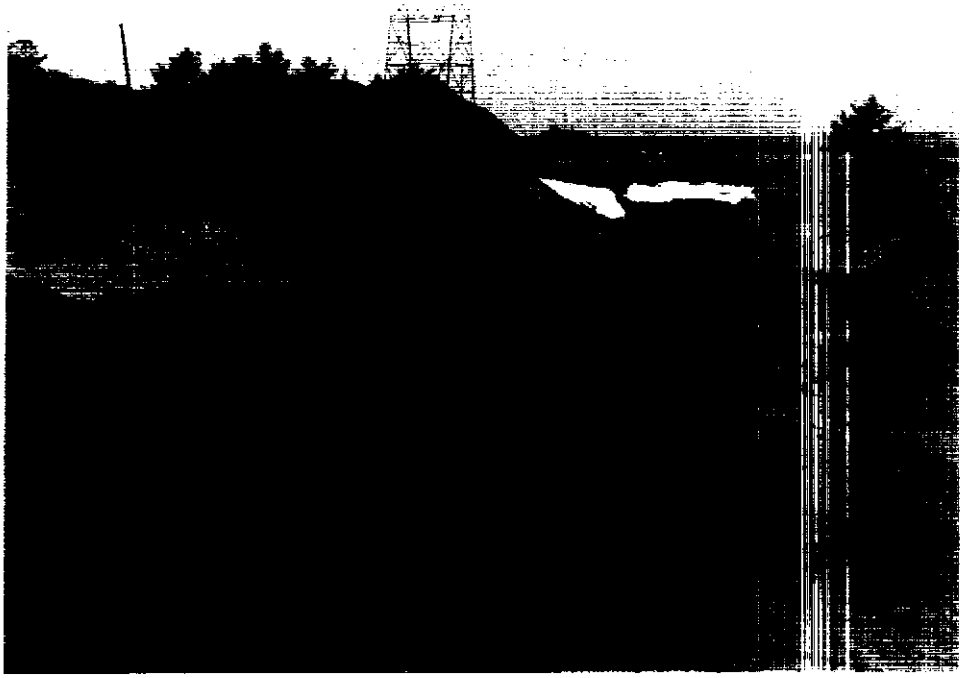
7 0 7 14
scale miles

JOB NO. 893-6255	SCALE 1" = 7 miles	**POTENTIAL BORROW SOURCE LOCATION MAP**	
DRAWN EAM	DATE 08/30/90		
CHECKED	DWG. NO. MA01-129		
Golder Associates		ISRT/WOBURN/MA	FIGURE 1

152110

Color

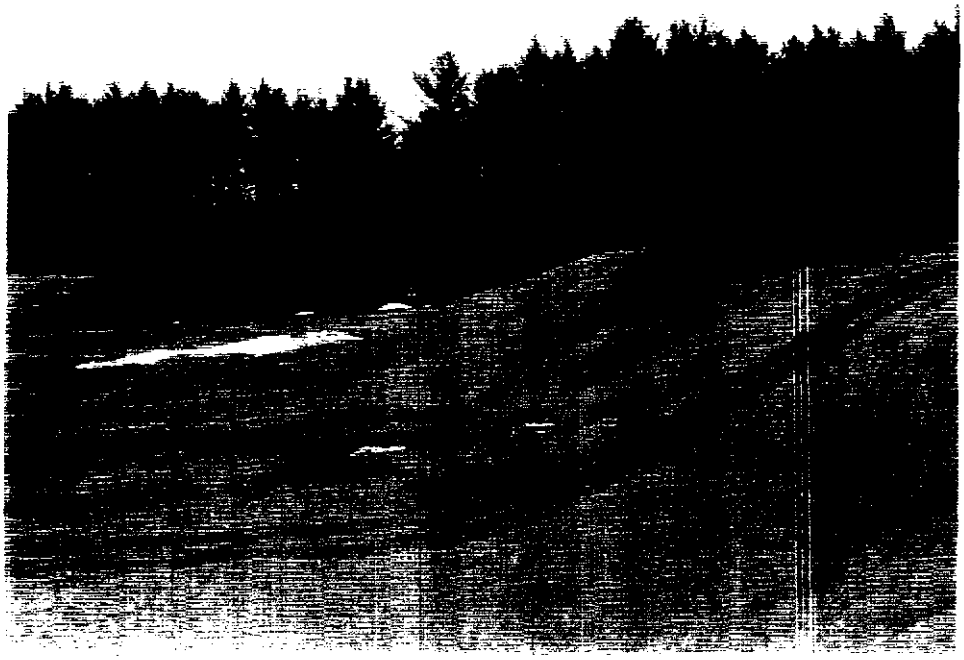




Originals in color

JOB NO. 893-6255	SCALE N/A	**ASHBURNHAM BORROW PIT ROUTE 12 ASHBURNHAM, MASSACHUSETTS**	
DRAWN SN	DATE 03/14/90		
CHECKED JEW	DWG. NO. MA01-130		
Golder Associates		ISRT/WOBURN/MA	FIGURE 2

152978



Originals in color.

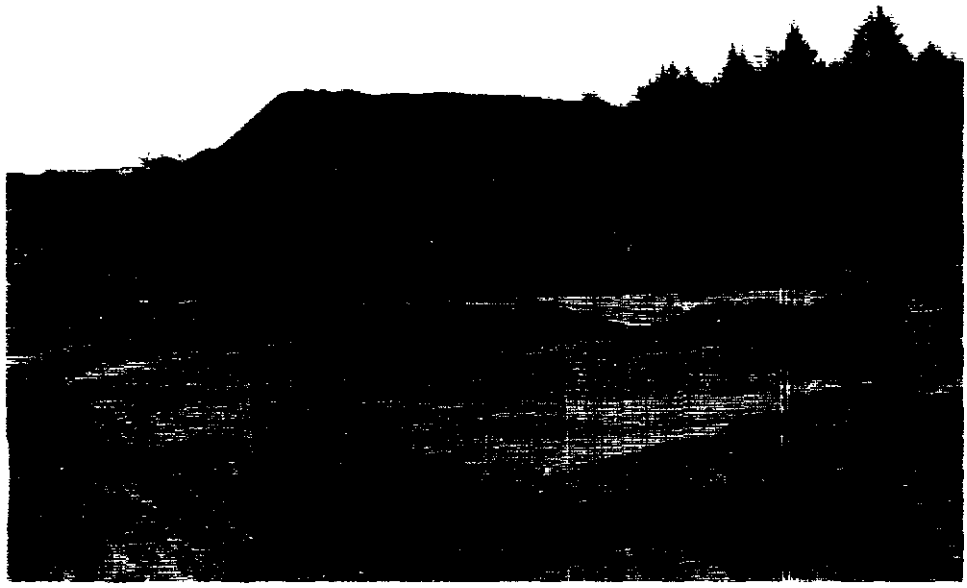
JOB NO. 893-6255	SCALE N/A	**TOWNSEND BORROW PIT MASON ROAD TOWNSEND, MASSACHUSETTS**	
DRAWN SN	DATE 03/14/90		
CHECKED JEW	DWG NO MA01-131		
Golder Associates		ISRT/WOBURN/MA	FIGURE 3

152978

Originals in color

JOB NO 893-6255	SCALE N/A	**WINCHENDON BORROW PIT MILL GLEN ROAD WINCHENDON, MASSACHUSETTS**	
DRAWN SN	DATE 03/14/90		
CHECKED JEW	DWG NO MA01-132		
Golder Associates		ISRT/WOBURN/MA	FIGURE 4

152978



Originals in color.

JOB NO 893-6255	SCALE N/A	**HUBBARDSTOWN BORROW PIT**	
DRAWN SN	DATE 03/14/90	**PITCHERVILLE ROAD**	
CHECKED JEW	DWG NO MA01-133	**HUBBARDSTOWN, MASSACHUSETTS**	
Golder Associates		ISRT/WOBURN/MA	FIGURE 5

152978

Originals in color.

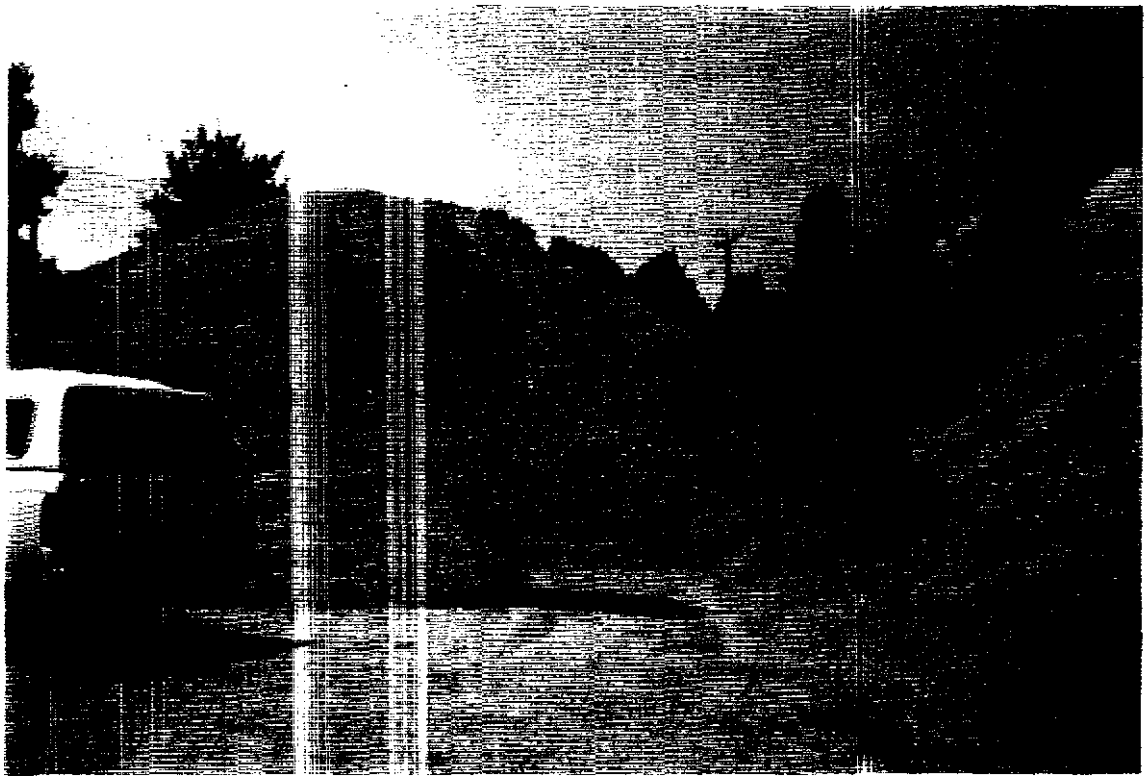
JOB No.: 893-6255	SCALE: N/A	**BILLERICA TOPSOIL STOCKPILE BILLERICA, MASSACHUSETTS**	
DRAWN: EAM	DATE: 09/04/90		
CHECKED: JEW	DWG. No.: MA01-134		
Golder Associates		ISRT/WOBURN/MA	FIGURE 6

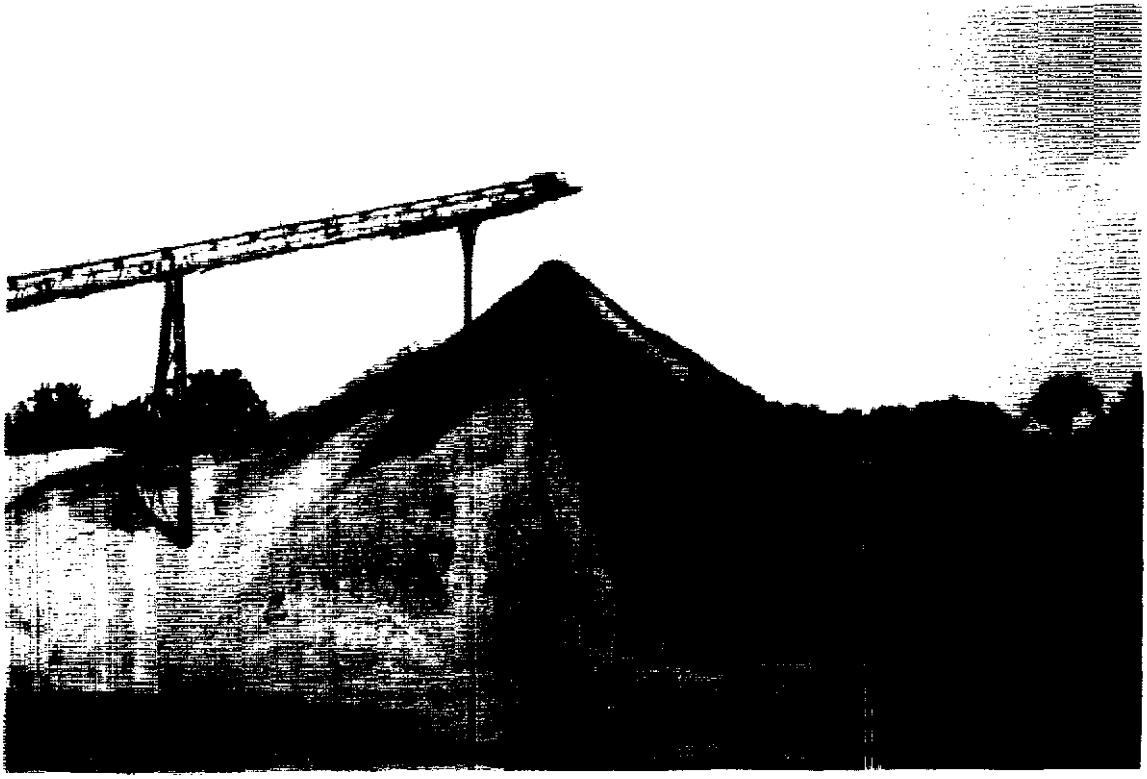
158896

Originals in color

JOB No.: 893-6255	SCALE: N/A	**KANE PERKIN'S SCREENED AND UNSCREENED TOPSOIL STOCKPILES HUDSON, MASSACHUSETTS**	
DRAWN: EAM	DATE: 09/04/90		
CHECKED: JEW	DWG. No.: MA01-135		
Golder Associates		ISRT/WOBURN/MA	FIGURE 7

158696





Originals in color.

JOB No.: 893-6255	SCALE: N/A	QUINN PERKIN'S SAND AND GRAVEL STOCKPILES BURLINGTON, MASSACHUSETTS	
DRAWN: EAM	DATE: 09/04/90		
CHECKED: JEW	DWG. No.: MA01-136		
Golder Associates		ISRT/WOBURN/MA	FIGURE 8

158896

APPENDIX A

Geosynthetics Product Information

Geotextile Product Information

Information on

Amoco Fabrics & Fibers Company
900 Circle 75 Parkway
Suite 500
Atlanta, Georgia
30339

Amoco Fabrics and Fibers Company

Amoco Fabrics and Fibers Company is the only producer of both woven and nonwoven geotextile fabrics worldwide with manufacturing facilities in the U.S., Canada, Brazil, Scotland, England, Germany, and Australia. With U.S. manufacturing facilities in Roanoke, AL, Andalusia, AL, Bainbridge, GA, Nashville, GA, and Hazlehurst, GA, Amoco makes products ranging from carpet backing, carpet face yarns, industrial bags to nonwovens for hazardous waste landfill filtering and cushioning applications. These are just a few of the many varying applications in which Amoco is a leading supplier.

A.W. Olson is President of Amoco Fabrics and Fibers Company's North America operations located at:

900 Circle 75 Pkwy.
Suite 550
Atlanta, GA 30339

Amoco's nonwoven fabric manufacturing facility is located on Alma Highway in Hazlehurst, Georgia, 31539. The Plant Manager is Duke Campbell and Wesley Morrison is the Quality Control Manager. A complete history of Amoco Fabrics and Fibers is enclosed.

Amoco's nonwoven manufacturing process is a needle punched process which utilizes staple polypropylene fibers. The weight range of fabrics produced is 2.1 ounces per square yard to 20 ounces per square yard. The maximum continuous width for each product is 15 feet.

Fabric Quality Control

During the production of any nonwoven fabrics, samples reporting 10% of production are taken to the Quality Control Lab for acceptance testing. These samples are tested for fabric weight, tensile strength, elongation, thickness, trapezoidal tear strength, puncture strength and burst strength to verify property conformance. Fabric permeability, ultraviolet strength retention and apparent opening size properties are tested on a random basis at less frequent intervals because of time requirements for each test.

If lab tests reveal property conformance, production continues and sampling resumes on material at regular intervals. This frequency is considered standard procedure but may increase if deemed necessary by the process engineer. If the sample tested is not in conformance with any one of the properties specified, the process is corrected and the next available sample is taken to the Quality Control lab. Production quantities represented by nonconforming samples are downgraded for later disposition. Standard procedures resume once samples tested prove to be in conformance with requirements.

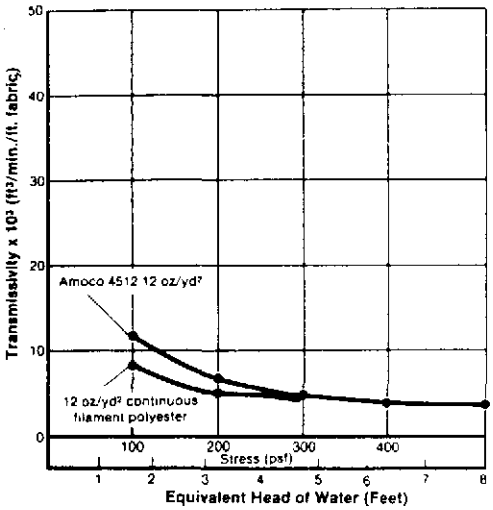
Quality control data generated corresponds to master rolls of approximately 1000 linear yards. Each master roll is packaged into smaller finished rolls for shipping in sizes specified for each product style. Piece or roll numbers are assigned to individial finished roll for inventory indentification and quality control purposes.

Test methods used in Amoco's Quality Control Department are current ASTM standard procedures for testing fabrics. Testing equipment calibration is performed at regular intervals based on industry standards or as recommended by the equipment manufacturers. Calibration records, statistical process control charts, and other quality control records are retained by the quality control department.

POLYPROPYLENE
The most INERT textile polymer available

Polypropylene is obtained from propylene gas, a by-product of oil refining. It is resistant to commonly encountered soil chemicals, mildew, and insects and is non-biodegradable. In fact polypropylene is the polymer of choice for such commonly used products as synthetic grass for athletic fields, outdoor carpeting, battery cases, bleach bottles, antifreeze jugs, washing machine agitators, and thousands of other commonly used items that are routinely exposed to a broad range of chemical and environmental conditions.

Polypropylene is stable within a pH range of 3 to 13 making it one of the most stable polymers available for fabric productions. When treated against ultraviolet exposure (as all Amoco Civil Engineering Fabrics are) polypropylene is stable to natural degradation and chemical attack.



Typical Transmissivity Response versus Applied Normal Stress for Various Needled Nonwoven Geotextiles

- With a specific gravity of 0.92, polypropylene needle punched fabrics are over 40% bulkier than equivalent weight polyester fabrics.
- As a result, polypropylene fabrics are much thicker per unit weight and provide better cushioning to protect against both puncture and abrasion.

Quality Geotextiles For:

1. **Cushioning:** A low cost way to help protect geomembranes from puncture and abrasion.
2. **Separation:** Provides a clean working surface to ensure better seams.
3. **Venting:** Provides a venting path for gases and liquids, both laterally and on slopes.
4. **Protection:** Adds overall strength to geomembrane.

Amoco Fabrics and Fibers Company
900 Circle 75 Parkway
Suite 300
Atlanta, Georgia 30339
(404) 984-4444

AMOCO NONWOVEN GEOMEMBRANE UNDERLINER FABRICS

SPECIFICATIONS

Typical Properties	Test Method	4504	4506	4508	4510	4512	4516
Weight, oz./s.y.		4.0	6.0	8.0	10.0	12.0	16.0
Grab Tensile, lbs.	ASTM-D-4632	125/100	210/170	285/230	350/270	425/315	570/400
Grab Elongation, %	ASTM-D-4632	60/55	60/55	65/55	70/60	70/60	70/60
Mullen Burst, psi	ASTM-D-3786	250	370	495	620	740	990
Puncture, lbs.	ASTM-D-4833-88	70	105	150	180	215	285
Trapezoidal tear, lbs.	ASTM-D-4533	55/45	80/65	105/85	140/110	165/130	220/190
AOS	ASTM-D-4751	70-120	70-140	70-200	100-200	100-400	100-400
Coefficient of Permeability, cm/sec	*ASTM-D-4491*	*.35*	*.31*	*.27*	*.26*	*.25*	*.23*
Permittivity, gal/min/ft²	ASTM-D-4491	150	110	100	80	70	60
Thickness, mils	ASTM-D-1777	50	85	115	130	175	215

Minimum Average Roll Values	*Test Method*	4504	4506	4508	4510	4512	4516
Grab Tensile, lbs.	ASTM-D-4632	85	150	200	235	275	325
Grab Elongation (min.)%	ASTM-D-4632	50	50	50	50	50	50
Mullen Burst, psi	ASTM-D-3786	225	350	450	550	650	750
Puncture, lbs.	ASTM-D-4833-88						
	3878(mod.)	55	90	130	165	200	260
Trapezoidal tear, lbs.	ASTM-D-4533	35	65	80	95	115	130
A O S *(minimum)*	ASTM-D-4751	70	70	70	100	100	100
Coefficient of Permeability, cm/sec	ASTM-D-4491	.2	.2	.2	.2	.2	.2
Permittivity, gal/min/ft²	ASTM-D-4491	100	90	80	70	60	50
Thickness, mils	ASTM-D-1777	40	75	90	110	150	195
U.V. Resistance, %[2]	ASTM-D-4355[1]	70	70	70	70	70	70

1. Fabric conditioned per ASTM-D-4355
2. Percent of minimum grab tensile after conditioning.

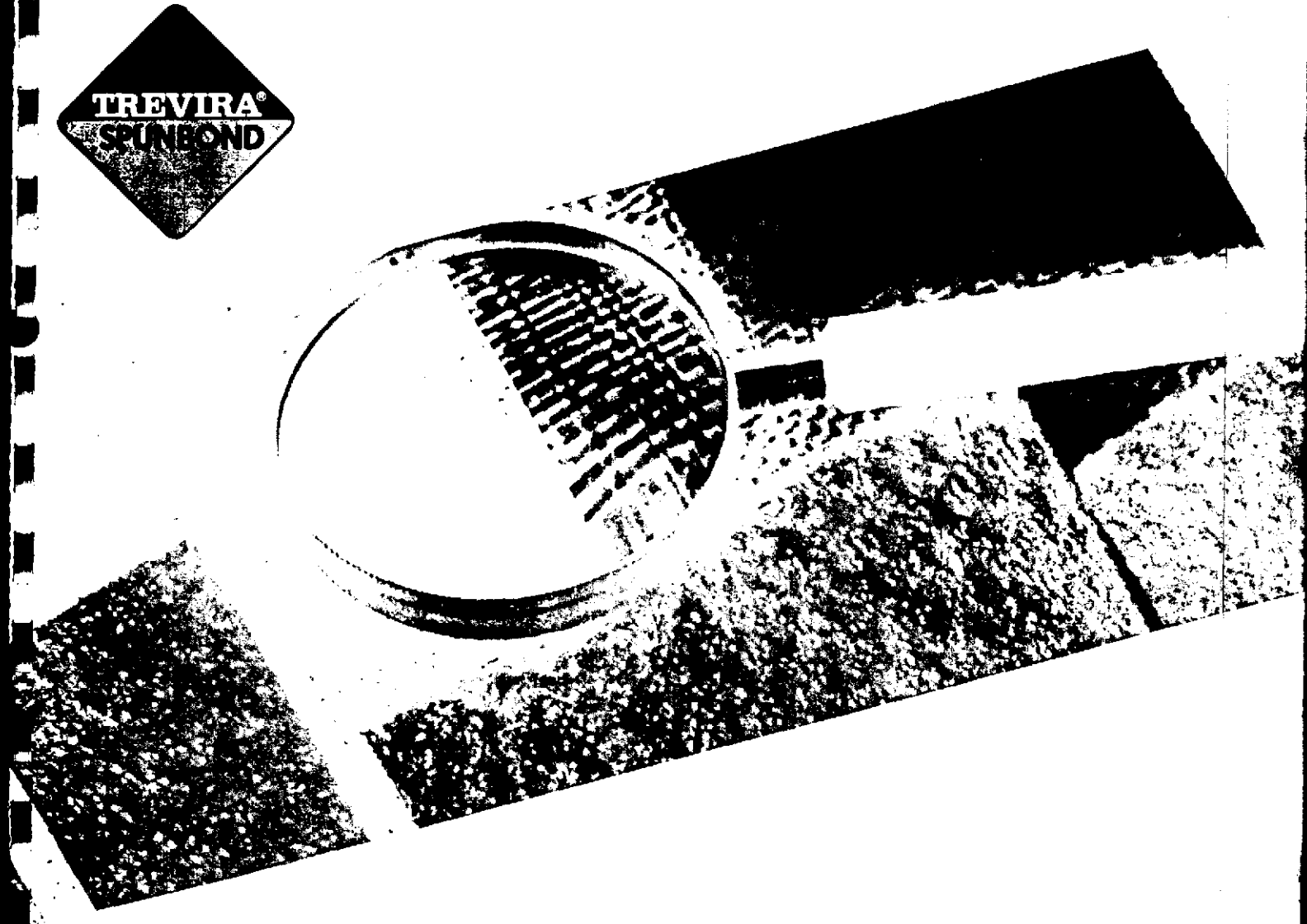
PACKAGING						
Roll width, ft.	15	15	15	15	15	15
Roll length, ft.	1,200	900	600	600	450	300
Approx. weight, lbs.	500	550	500	600	550	500
Area, square yards	2,000	1,500	1,000	1,000	750	500

END USE APPLICATIONS AND RECOMMENDED SOLUTIONS

REQUIREMENT	RECOMMENDED AMOCO UNDERLINER FABRIC
Clean working surface to insure efficient seaming.	4504, 4506, 4508
Higher abrasion and puncture resistance to increase liner protection.	4510, 4512, 4516
A higher functional surface to reduce liner slippage.	All Amoco Underliner Fabrics.
A separation/filtration system to reduce clogging of filtering system.	4504, 4506
Sufficient venting/transmissivity to provide lateral transmission of liquids and gases.	4508, 4510, 4512
The most inert material available resistant to the widest range of chemicals.	All Amoco polpropylene geomembrane underliner fabrics.

TREVIRA® SPUNBOND ENGINEERING FABRIC

THE PLAIN FACTS



Hoechst

The Plain Facts

The Plain Facts of engineering fabrics:

- **Engineering Fabrics: Close-Up!**
- **Product Uniformity**
- **Effect of Restraint**
- **Effect of Puncture**
- **Soil Retention**
- **Resistance to Heat**
- **Resistance to Creep**

All too often, the comparison of properties, such as physical strength, etc., of engineering fabrics is based upon published literature.

The need to understand the true nature and function of engineering fabrics in installations requires more information than just typical (average) physical values.

This literature provides, in a simple format, information to better understand the differences between nonwoven and woven fabrics and between polyester and polypropylene fabrics.

The information provided will establish:

- Needlepunched Nonwovens are multi-directional
- Wovens are bi-directional
- Needlepunched Nonwovens outperform Wovens in:
  - Permeability
  - Soil retention
  - Conformability
  - Lateral restraint
- For any given installation, strength requirements for wovens are significantly higher than for Nonwovens (interface friction, 360° performance).
- Needlepunched Nonwovens have the necessary high aggregate/fabric friction to provide lateral restraint.
- Wovens fail to provide lateral restraint due to low aggregate/fabric friction and accumulation of moisture at the soil/fabric interface.
- Needlepunched Continuous Filament Nonwovens are virtually uneffected by punctures based upon strength.
- Wovens significantly weaken, elongate and tear after a puncturing.
- Needlepunched Nonwovens are unsurpassed in retaining soil and maintaining water flow.
- Polyester is unsurpassed in resistance to heat.
- Polyester is unsurpassed in resistance to creep.
- Polyester is unsurpassed in resistance to hydrocarbons.

WOVEN and NONWOVEN

Woven engineering fabrics are constructed by meshing fiber strands in a perpendicular fashion.

Since the *woven* fiber strands are oriented in only two directions, fabric strength and elongation characteristics are directionally dependent. Furthermore, significant directional strength differences exist for many woven fabrics (up to 40%).

Actual field loads are applied in multi-directional patterns. Thus the true measure of a woven or nonwoven fabric is determined by examining the physical properties in a 360 degree analysis as provided in this literature.

Nonwoven fabrics like TREVIRA® are constructed of fibers oriented in a random pattern.

The controlled, random orientation provides *multi-directional* strength and elongation properties.

Nonwoven fabrics' thickness and fiber orientation insure superior soil retention while allowing ample water permeation. Thicker *nonwovens* provide a plane for pore water pressure dissipation and water flow within the fabric itself.

Nonwovens are pliable and conform far more readily to subgrade and ballast irregularities, thus providing more intimate contact with the soil, and higher aggregate/fabric restraint.

HEATBONDED and NEEDLEPUNCHED

Heatbonding and needlepunching are manufacturing techniques to fashion fibers into nonwoven fabrics.

Heatbonding fibers into a nonwoven fabric is accomplished by pressing the fibers together under heat, partially melting the fibers together at the fiber overlaps.

Heatbonding fibers causes indentations in the fiber, causing stress concentrations, resulting in lower tear and puncture strengths, as well as causing the fabric to be board-like, thus reducing the fabric's conformability significantly.

Heatbonding severely inhibits the fabric's ability to conduct water within the plane of the fabric. *Heatbonding* significantly reduces the lateral restraint of aggregate in contact with the fabric due to low aggregate/fabric friction.

Needlepunching is a *mechanical* interlocking of the fibers without heat, pressure, or resins.

Needlepunching produces a superior pliable, thick, multi-directional strength fabric with no stress concentrations or directional weaknesses as wovens or heatbonded nonwovens.

Needlepunching allows the fabric to conform to the subgrade, while allowing for controlled soil retention and superior water flow characteristics over all other types of nonwoven bonding.

SUMMARY

"The Plain Facts" of engineering fabrics provided you with important concepts:

- **Engineering Fabrics: Close-Up!**
- **Effect of Restraint**
- **Product Uniformity**
- **Effect of Puncture**
- **Soil Retention**
- **Resistance to Heat**
- **Resistance to Creep**

All too often, the comparison of properties, such as physical strength, etc., of engineering fabrics is based upon published literature.

The information provided has established:

- Needlepunched Nonwovens are multi-directional
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  - Conformability
  - Lateral restraint
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- Polyester is unsurpassed in resistance to heat.
- Polyester is unsurpassed in resistance to creep.
- Polyester is unsurpassed in resistance to hydrocarbons.

The facts justify using a needlepunched continuous filament polyester nonwoven.

PRODUCT DESCRIPTION

TREVIRA® Spunbond products are 100% polyester (poly-ethylene terephthalate), continuous filament fabrics mechanically bonded by needling.

TREVIRA Spunbond Type 11 fabrics are produced in weights from 4.5 through 16 oz/yd² and in a light grey color.

TYPICAL PHYSICAL PROPERTIES OF TYPE 11 PRODUCTS

Fabric Type	1115	1120	1127	1135	1145	1155
Fabric Weight (oz/yd²)	4.5	6	8	10	13	16
Thickness (Mils) (ASTM D-1777)	85	100	125	150	175	210
Grab Strength (LB, MD/CD*) (ASTM D-1682)	130/110	175/155	260/225	340/300	430/390	525/485
Grab Elongation (%, MD/CD) (ASTM D-1682)	85/95	85/95	85/90	90/95	90/95	90/95
Trapezoid Tear Strength (LB, MD/CD) (ASTM D-1117)	50/45	65/60	100/95	130/130	185/180	205/200
Puncture Strength — 5/16" (LB) (ASTM D-751)	60	90	125	155	200	260
Mullen Burst Strength (PSI) (ASTM D-3786)	220	300	380	500	600	800
Vertical Water Flow (GAL/MIN/FT²) (HFI Test)	325	300	280	265	240	220
EOS (CW-02215)	70 +	50-70	70-100	70 + -100 +	100-120	120 +
Std. Roll Widths (FT)	12.5, 14.5, & 16.0					
Std. Roll Length (FT)	300 & 1000				300 & 600	

*MD = Machine Direction, CD = Cross Machine Direction. Special width and length rolls are available upon request.

NOTE: Typical Physical Properties of Type 11 Products represent typical average values as opposed to specification values. For recommended end use specifications and physical propeties, contact your TREVIRA Spunbond Distributor.

Hoechst

Hoechst Fibers Industries
Spunbond Business Unit
P. O. Box 5887
Spartanburg, SC 29304
Telephone 1-800-845-7597

Trevira® Spunbonds are highly needled nonwoven engineering fabrics with excellent tensile properties, high filtration potential and outstanding permeability.

Trevira® Spunbond Type 11 products are 100% continuous filament polyester nonwoven needlepunched engineering fabrics. They deliver a combination of advantages unmatched by any other spunbonded geotextiles. They're resistant to freeze-thaw, soil chemicals and ultraviolet light exposure.

Trevira® Spunbonds are excellent where the requirement is (1) tensile reinforcement, (2) planar flow, (3) filtration, and (4) separation. For example, in roadways, railbeds, drainage systems, pondliners, retaining walls. And much more. Trevira® Spunbonds are extraordinary engineering fabrics.

TYPICAL PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PRODUCTS

Fabric Property	Unit	Test Method	1112	1114	1120	1125	1135	1145	1155
Fabric Weight	oz/yd²	ASTM D-3776	3.6	4.2	6.0	7.4	10.5	13.5	16.2
Thickness, t	mils	ASTM D-1777	60	65	90	110	150	175	210
Grab Strength (MD/CD)[1]	lbs	ASTM D-4632	110/90	135/110	205/175	270/225	390/330	500/425	625/560
Grab Elongation (MD/CD)	%	ASTM D-4632	70/85	70/85	75/85	75/85	75/85	90/95	90/95
Trapezoid Tear Strength (MD/CD)	lbs	ASTM D-4533	50/40	60/50	80/75	105/95	135/120	175/170	205/200
Puncture Resistance (5/16" hemispherical tip)	lbs	ASTM D-3787	50	60	90	115	155	175	240
Mullen Burst Strength	psi	ASTM D-3786	180	210	315	390	550	625	840
Water Flow Rate	gpm/ft²	ASTM D-4491	150	140	130	120	100	80	55
Permittivity, Ψ	sec⁻¹	ASTM D-4491	2.04	1.90	1.77	1.63	1.36	1.09	0.75
Permeability, k	cm/sec	k = Ψt	0.31	0.31	0.40	0.46	0.52	0.48	0.40
AOS	Sieve Size mm	CW-02215 Mod. to 10 Min.	70-100 .210-.149	70-100 .210-.149	70-100 .210-.149	70-120 .210-.125	70-120 .210-.125	100-140 .149-.105	100-170 .149-.088
Standard Roll Widths[2]	ft		12.5 and 15.0						
Standard Roll Length[2]	ft		400	400	300	300	300	300	300

[1]MD = Machine Direction, CD = Cross Machine Direction.

[2]Other width and length rolls are available upon request.

MINIMUM AVERAGE ROLL VALUES (WEAKEST PRINCIPAL DIRECTION) OF TREVIRA® TYPE 11 PRODUCTS

Fabric Property	Unit	Test Method	1112	1114	1120	1125	1135	1145	1155
Fabric Weight	oz/yd²	ASTM D-3776	3.4	4.0	5.7	7.1	10.0	13.0	16.0
Thickness, t	mils	ASTM D-1777	50	55	80	100	135	160	200
Grab Strength	lbs	ASTM D-4632	80	100	155	200	290	375	500
Grab Elongation	%	ASTM D-4632	60	60	65	60	65	80	80
Trapezoid Tear Strength	lbs	ASTM D-4533	30	40	60	75	100	140	170
Puncture Resistance (5/16" hemispherical tip)	lbs	ASTM D-3787	35	45	75	95	130	155	200
Mullen Burst Strength	psi	ASTM D-3786	160	190	285	360	500	575	765
Water Flow Rate[3]	gpm/ft²	ASTM D-4491							
Permittivity, Ψ[3]	sec⁻¹	ASTM D-4491							
Permeability, k[3]	cm/sec	k = Ψt							
AOS[4]	Sieve Size mm	CW-02215 Mod. to 10 Min.	70 .210	70 .210	70 .210	70 .210	70 .210	100 .149	100 .149

[3]Insufficient testing has been performed to statistically establish "minimum average values" at the time of this printing. Please contact your Trevira Distributor or Hoechst Fibers for additional information.

[4]AOS "minimum average roll value" is a measure of the *largest* opening size in the fabric.

Hoechst Fibers Industries
A division of American Hoechst Corporation
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Spartanburg, SC 29304-5887 U.S.A.
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Telex: 530 799

Hoechst


polyfelt
Geotextiles
Specified by
experts worldwide

The outstanding quality of Polyfelt geotextiles is a result of the following physical properties

Needlepunching of filaments provides

- Three-dimensional porous structure and excellent filter properties
- Excellent elasticity to absorb dynamic installation forces
- Optimal tensile elongation to avoid areas of excessive strain at point stress (deformation under stones of up to 40% and more are often required)
- Excellent interlocking with the shape of revetments or fill material to prevent sliding failure
- Uniform tensile strength in all directions
- High water permeability, both horizontally and vertically
- Voluminous structure provides ideal protection for geomembranes
- Filter characteristics that remain stable even under stress

Use of continuous filaments ensures

- High tensile strength even in low weight products
- No unravelling of the filaments
- Consistent high quality product (no addition of low quality fibers or polymers)
- Optimum filament structure

Use of UV stabilized polypropylene raw material gives

- Eight times higher ultra-violet stability compared to unstabilized polypropylenes
- No danger of hydrolysis (i.e. no molecular degradation through water and heat)
- Excellent stability against acid, alkaline and microbiological attacks
- Develops no by-products — it is absolutely environmentally compatible
- No changes due to various climatic conditions (frost, humidity, temperature changes)
- Optimum long-term behaviour

"Specified by Experts Worldwide"

Polyfelt's worldwide manufacturing, distribution and application engineering services are available to assist you with your geotextile project. Please contact our regional office nearest you.

Polyfelt is economical

POLYFELT has proven itself a reliable geotextile for decades by withstanding severe installation conditions worldwide.

Installation on the construction site is easy.

Delivery is prompt and reliable.

POLYFELT roll sizes allow practical handling on site.

POLYFELT can be cut with a knife.

POLYFELT is easy to join

- by overlapping (at least 12")
- by welding (by means of gas burners, overlapping 4-6")
- by sewing

The advantages of using Polyfelt are:

- reduction or complete substitution of mineral filter layers
- reduced amounts of fill material for roads and embankments
- extended life of buildings and structures
- reduced construction time
- increased load-bearing capacity
- accelerated consolidation time
- guaranteed continuous drainage function
- substitutes soil replacement and therefore saves energy, time, material and space requirements for containments
- fast and easy placement — without specialist knowledge

Economical and technical reliability is ensured with Polyfelt in the execution of a wide variety of projects.

Polyfelt geotextiles are technically reliable

Every project has unique factors which influence decisions made about the type of geotextile to be selected.

POLYFELT products are manufactured in a range of grades specially designed to meet the demands of any geotextile application.

Detailed design information and POLYFELT applications engineers are available to provide technical support and design assistance specific to your project needs:

1. POLYFELT's *Design and Practice Manual* — Precisely defines design criteria for the selection of the suitable geotextile product.
2. Test results using special soil/POLYFELT systems.
3. Recommendations for project design.

Design recommendations combine standard engineering methods and practice with the results of extensive scientific research and practical experience gained on major projects internationally. These factors make possible exact determination of the geotextile requirement and selection of the optimum POLYFELT type with respect to economic benefits and technical reliability.

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Tel: 6 (03)

General Information

1. Geotextile Classification

Structure	NONWOVEN	WOVEN	KNITTED
Raw Material	Polypropylene, Polyester, Polyamide, Polyethylene, Nylons, etc.		
Fiber Type	Continuous Filament Staple Fiber	Monofilament Multifilament Slit Film Fibrillated	Multifilament
Bonding Process	Needlepunched Heatbonding	Weaving	None

2. Polyfelt TS Geotextile Characteristics

2.1 Composition

Polyfelt TS geotextile is comprised of approximately 99 percent polypropylene. The remaining 1 percent account for U.V. stabilizer and the color pigmentation.

2.2 Structure

Nonwoven: The fibers are arranged in an oriented or random pattern into a planar structure.

2.3 Fiber

Continuous Filament: The filaments are produced by continuously extruding melted polymer through dies or spinnerets. Fiber and fabric are made in one continuous manufacturing facility.

2.4 Bonding

Needlepunched: Thousands of small barbed needles, set into a board, punch through the loose fiber web and withdraw, leaving fibers entangled.

2.5 Ultraviolet Stabilization

Chemically U.V. stabilized: By adding proprietary chemical additive, Polyfelt TS geotextiles are able to better resist the damaging effects of the sun and absorb ultraviolet radiation. Most other geotextiles in the market are stabilized using the additive carbon black.

3. Product Definition

Based on the above geotextile characteristics, Polyfelt TS is described as a polypropylene, nonwoven, continuous filament, needlepunched chemically U.V. stabilized geotextile.

The manufacturing technique used to make Polyfelt TS geotextiles results in a fabric with optimum technical properties which are required in engineering construction. A summary of these properties are:

- Excellent stress-strain behavior
- Good flexibility
- Excellent filtering characteristics
- High water permeability
- Excellent mechanical protection
- Can be welded together
- Does not form by-products
- High resistance to climatic conditions
- Highly resistant to all chemical and biological attack
- Chemically U.V. stabilized

TYPICAL ROLL PROPERTIES

PROPERTY	TEST PROCEDURE	UNIT	POLYFELT 420	500	550	600	650	700	750	800	900	1000	PGM 13	15	20
PHYSICAL															
Weight	ASTM D3776	oz/yd²	3.8	4.5	5.5	6.0	7.0	8.3	10.3	12.0	14.0	16.2	3.6	4.2	6.0
Thickness	ASTM D1777	mils	55	60	70	80	90	105	120	130	150	160	55	60	80
Asphalt Retention	TF25, Meth. B	gal/yd²											0.22	0.27	0.33
MECHANICAL															
Grab Tensile	ASTM D4632	lbs	110	125	150	170	190	225	280	325	*380/320	*470/350	100	120	160
Grab Elongation	ASTM D4632	%	>50	>50	>50	>50	>50	>50	>50	>60	*85/90	*90/95	>50	>50	>50
Wide-Width Tensile	ASTM D4595	lb/in	45	50	65	75	85	100	120	135	145	150			
Elongation at Break	ASTM D4595	%	>50	>50	>50	>50	>50	>50	>55	>55	>80	>80			
Puncture Resistance	ASTM D4833	lbs	55	65	70	85	100	115	130	150	155	170	55	60	85
Trapezoidal Tear	ASTM D4533	lbs	50	60	70	75	85	100	115	130	*150/135	*170/140	50	55	75
Mullen Burst	ASTM D3786	psi	155	185	230	255	295	345	425	450	470	490			
HYDRAULIC															
Water Flow Rate	ASTM D4491	gpm/ft²	250	220	190	170	140	130	100	90	80	65			
Permittivity	ASTM D4491	sec⁻¹	2.9	2.7	2.3	2.0	1.8	1.6	1.3	1.2	0.9	0.8			
Permeability, Kv	ASTM D4491	cm/sec	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.35	0.35			
Transmissivity at	ASTM D4716	gpm/ft (x10⁻²)													
0.3 psi			6.7	7.0	8.5	9.5	10.0	11.0	11.5	12.7	13.0	15.0			
14.5 psi			2.7	3.0	3.8	4.0	5.0	7.0	7.0	7.0	7.0	7.0			
29.0 psi			1.6	2.0	2.5	3.0	3.5	4.0	4.0	4.0	4.0	4.0			
A.O.S.	ASTM D4751	sieve size	70-35	80-40	80-45	100-60	100-70	120-80	140-100	140-100	>140	>140			
		mm	0.2-0.5	0.18-0.42	0.18-0.35	0.15-0.25	0.15-0.21	0.12-0.18	0.10-0.15	0.10-0.15	<0.10	<0.10			
ENDURANCE															
U.V. Resistance (500 hours)	ASTM D4355	% str. ret.	>85	>85	>85	>85	>85	>85	>90	>90	>90	>90			
pH Resistance			2-13	2-13	2-13	2-13	2-13	2-13	2-13	2-13	2-13	2-13	2-13	2-13	2-13

MINIMUM AVERAGE ROLL PROPERTIES

PROPERTY															
Grab Tensile	ASTM D4632	lbs	90	110	130	140	170	205	245	300	310	320	90	100	140
Grab Elongation	ASTM D4632	%	50	50	50	50	50	50	50	60	80	80			
Puncture Resistance	ASTM D4833	lbs	45	50	60	70	85	95	115	130	135	140	45	50	70
Trapezoidal Tear	ASTM D4533	lbs	45	50	60	65	75	85	95	105	110	120	45	50	65
Mullen Burst	ASTM D3786	psi	135	160	200	220	260	300	380	400	425	450			

*MD/CD

PACKAGING

ROLL													
Width, ft	15	15	15	15	15	15	14	13	10	10	12.5	12.5	12.5
Length, ft	360	360	360	360	360	360	300	300	300	300	400	575	360
Area, yd²	600	600	600	600	600	600	467	433	333	333	556	799	500
Weight, lbs	150	180	215	235	275	320	310	335	300	345	148	231	200

polyfelt

Nonstandard roll dimensions are available on request and subject to a minimum quantity. Mechanical properties based on standard roll width.

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Geomembrane Product Information

For environmental lining solutions...the world comes to SLT.

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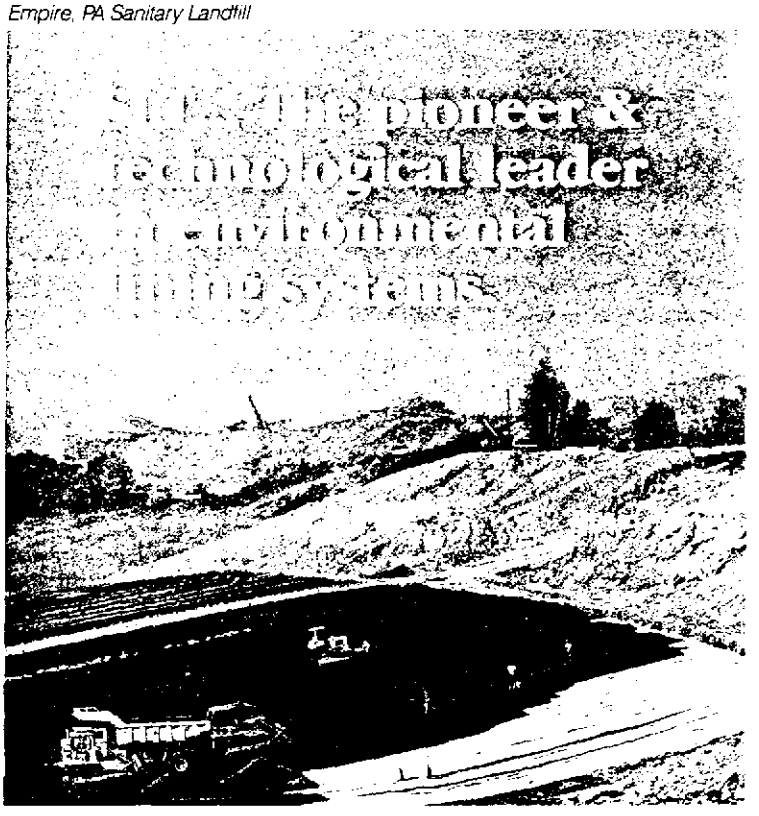
SLT®

SLT North America, Inc.

SLT is the pioneer in HDPE lining systems and the technological leader in helping solve today's complex lining problems. Since the early 1970's, we have been providing quality HDPE liners and exceptional service to our clients worldwide. With manufacturing and Technical Facilities in the U.S. and West Germany, we have been at the forefront of developing and installing state of the art lining systems longer than anyone. Our multi-plant capability provides our customers assurance of supply, and our subsidiary companies in Australia and Singapore can provide high quality installations anywhere in the world.

Empire, PA Sanitary Landfill



Technological Leader

SLT is the only manufacturer of HDPE lining systems with worldwide technical facilities. We are geared toward developing new products and lining systems consistent with stringent environmental requirements. Our worldwide research efforts assure our customers of having state of the art products and installed lining systems which will be environmentally sound well into the future. In addition to innovations such as HyperFlex™, Polylock™, and DRS™, we have continued to pioneer and develop applications for floating covers, tunnel linings and high temperature resistance.

Turnkey Service

SLT provides a total turnkey system, from engineering and design to quality installation. All of our employees associated with design, Quality Assurance and installation of our liner systems are experienced and highly trained in membrane technology and installation techniques.

Our clients are among the leaders in the mining, waste management, power generation, chemical and petroleum industries. We have successfully helped our clients solve lining problems in applications such as:

- ☐ Heap Leach Pads
- ☐ Evaporation Ponds
- ☐ Dam Liners
- ☐ Ash Ponds
- ☐ Canals
- ☐ Secondary Containment Systems
- ☐ Sanitary Landfills
- ☐ Saltwater Disposal Systems
- ☐ Hazardous Waste Landfills
- ☐ Sewers and Hydro Tunnels
- ☐ Floating Covers
- ☐ Overflow Ponds
- ☐ Rinse Ponds
- ☐ Methane Barriers

Features of SLT's Complete Turnkey System:

- ☐ A pioneer's experience with over 500 million square feet of liner manufactured and installed worldwide.
- ☐ Multi-plant manufacturing facilities with worldwide installation capability.
- ☐ Complete engineering service, support, and follow-up.
- ☐ Research & Technical facilities in the U.S. & West Germany.
- ☐ Sheet thickness from 40 to 240 mil.
- ☐ 34' wide seamless, monolithic sheet.
- ☐ Use of Statistical Process Control (SPC) for manufacturing and installation of liner.
- ☐ Patented extrusion-welding process.
- ☐ Highly experienced and trained installation crews.
- ☐ Recently expanded manufacturing capacity.
- ☐ NSF Certification.

Benefits from choosing SLT for your next lining job:

- ☐ Confidence from knowledge that SLT has the experience, knowledge and capability to handle the most complex and difficult lining assignment.
- ☐ Assurance of supply and quality installation anywhere in the world.
- ☐ Assistance and support from our engineers with experience in all aspects of lining system design and installation.
- ☐ State of the art lining materials and lining systems designed to meet the most stringent environmental requirements.
- ☐ Wide selection of sheet thickness provides design flexibility and single source convenience and efficiency.
- ☐ Extra wide 34' sheet minimizes the number of seams necessary in field installation.
- ☐ Efficient and high quality turnkey installation.

- ☐ Use of Statistical Process Control (SPC) technique provides high quality sheet with zero-defects, thus greater assurance of superior environmental protection and long term containment.
- ☐ SLT's HyperFlex sheet improves dimensional stability, increases resistance to environmental stress cracking, and provides stronger weld strength than all competitive HDPE liner materials.
- ☐ A patented extrusion flat weld from SLT which produces a homogeneous installation seam with strength equal to or greater than the parent material.

SLT has the innovative technology, experience and manpower to handle any lining project, from the largest to the smallest, anywhere in the world. Contact us today to discuss the next project your company is planning. You can depend on the pioneer lining technology company that continues to break new ground in lining system advancements.

For environmental lining solutions... the world comes to SLT.

SLT®

SLT North America, Inc.
Subsidiary of SLT Environmental, Inc.
Four Greenspoint Plaza
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SLT North America, Inc.

For environmental lining solutions...the world comes to SLT.

HyperFlex™ Premium Grade HDPE Lining Material

SLT HyperFlex™ is uniquely produced from a specially formulated virgin HDPE geomembrane resin. HyperFlex™ has outstanding chemical resistance, mechanical properties, environmental stress crack resistance, dimensional stability and thermal aging characteristics. HyperFlex™ contains approximately 97.5% polymer and 2.5% carbon black, anti-oxidants, heat stabilizers, and contains no additives, fillers and extenders. HyperFlex™ has excellent resistance to U.V. radiation and is suitable for exposed conditions.

PROPERTY	TEST METHOD	NOMINAL VALUE		
Thickness	ASTM D751/1593/374	60mil	80mil	100mil
Density (g/cc)	ASTM D792/1505	0.944	0.944	0.944
Melt Flow Index (g/10 Minutes)	ASTM D1238-E	≤ 1.0	≤ 1.0	≤ 1.0
Tensile Properties Either Direction	ASTM D638 Type IV Dumbell, 2 ipm			
Tensile Strength at Break (lb/in Width)	Gauge length per	300	400	500
Tensile Strength at Yield (lb/in Width)	N.S.F. Std. 54	180	240	300
Elongation at Break (Percent)		800	800	800
Elongation at Yield (Percent)		15	15	15
Modulus of Elasticity (psi)		80,000	80,000	80,000
Tear Resistance Initiation (Pounds)	ASTM D1004 Die C	70	94	117
Low Temperature Brittleness	ASTM D746 B	-120°F	-120°F	-120°F
Dimensional Stability Percent Each Direction	ASTM D1204 248°F 1 hr.	±1	±1	±1
Volatile Loss (Max. Percent)	ASTM D1203 Meth. A	0.10	0.10	0.10
Resistance To Soil Burial	ASTM D3083			
Tensile Strength at Break or Yield	Percent Change	±5	±5	±5
Elongation at Break or Yield	Percent Change	±10	±10	±10
Ozone Resistance	ASTM D1149 7 days 100 pphm 104°F	No Cracks	No Cracks	No Cracks
Environmental Stress Crack Resistance (Minimum Hrs.)	ASTM D1693 Cond. C	5000	5000	5000
Puncture Resistance (Pounds)	FTMS 101C Method 2065	90	120	160
Water Adsorption (Percent Weight Change)	ASTM D570	0.0079	0.0079	0.0079
Coef. Linear Thermal Expansion 10^{-4}/°C	ASTM D696	1.2	1.2	1.2
Moisture Vapor Transmission (g/m^2day)	ASTM E96	0.001	0.0009	0.00085
Oxidative Induction Time (Minimum Minutes)	ASTM D3895			
Compressed O_2 at 800 psi	130°C	2300	2300	2300
Pure O_2 at 1 Atmosphere	200°C	100	100	100
Tensile Impact Strength (Ft Lb/in^2)	ASTM D1822	381	381	381

SLT HyperFlex™ is manufactured 32.7 feet wide and up to 900 feet long and is the world's largest monolithic geomembrane lining material.

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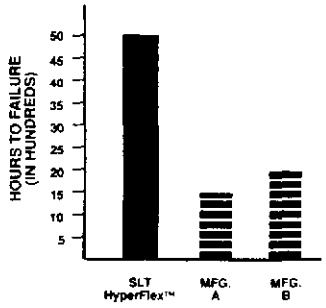
SL-0048B 2-90 2.5M

HyperFlex™ Premium Grade HDPE Lining Material

Standard tests prove SLT's HyperFlex™ is superior to conventional liners in mechanical properties and longevity. HyperFlex™ HDPE environmental lining material has undergone a series of tests which have yielded dramatic results when compared to conventional HDPE lining materials. These tests prove that HyperFlex™ offers these advantages over conventional HDPE liners from leading manufacturers:

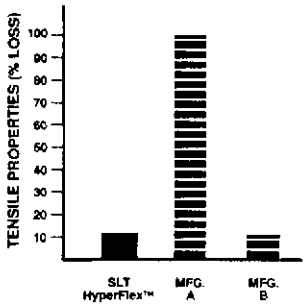
- Environmental stress crack resistance is superior to other HDPE liners by a factor over 3 times. This significantly enhances longevity and eliminates cracking and subsequent leaks.
- Dimensional stability is superior to other HDPE liners, especially in high temperature exposure. This measures the level of inherent residual stresses which can result in failure and leaks.
- Superior resistance to cold climates, which reduces embrittlement and failure due to cold environments.
- Superior field seam strength, which enhances containment integrity.
- Superior impact strength and increased toughness, thus providing integrity under full load.

HyperFlex™ Performance Comparison



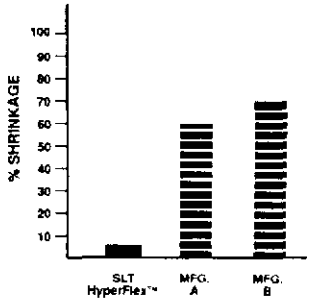
ESCR
ENVIRONMENTAL STRESS CRACK RESISTANCE ASTM D1693 'C'

Comparative results of laboratory simulation of expected combined effects of stress and corrosion on the liner material.



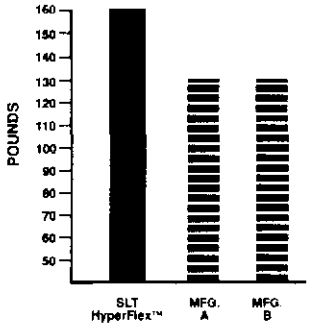
HEAT AGING
ASTM D794

Various liner materials were heated in a laboratory oven set at 116°C for 90 days. Tensile properties of each material were determined before and after the oven aging. SLT HyperFlex™ liner performed among the best by its excellent retention of tensile properties after heat aging.



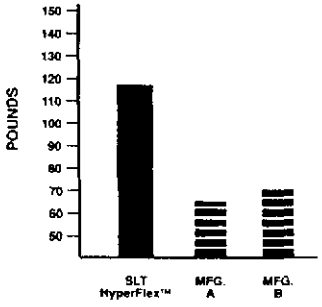
RESIDUAL STRESS ANALYSIS HIGH TEMPERATURE SHRINKAGE
ASTM D1693 SECTION 8.2

Exposure of liner material to temperature of 300°F to determine the dimensional stability and existing residual stress.



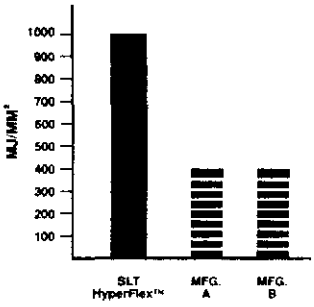
PUNCTURE RESISTANCE
FTMS 101C Method 2065 100 mil

Comparative laboratory results demonstrate the superior performance of HyperFlex™ in resistance to puncture.



TEAR RESISTANCE
ASTM D1004 DIE C 100 mil

Comparative laboratory results demonstrate the superior performance of HyperFlex™ in resistance to tear.



TENSILE IMPACT STRENGTH
(TOUGHNESS) ASTM D1822

The amount of energy required to rupture the liner material upon sudden impact is simulated through pendulum-type impact testing. This measures the degree of toughness of the liner.

This data is provided for informational purposes only and is not intended as a warranty or guarantee. SLT assumes no liability in connection with the use of this data.

Schlegel Lining Technology, Inc.
TECHNICAL BULLETIN

Chemical Resistance

A large percentage of lining installations that fail, *do so because of incompatibility* between the liner material and the contents of the basin. To prevent this type of failure it is essential to consider carefully the exact composition of both the liner and the contents of the basin.

The liner

Frequently, the chemical resistance of a lining material is determined by what is known about the liner's base material. For example, a liner might be called PVC, it is therefore assumed that the liner will have the chemical resistance of pure PVC. However, very few liners are made from a single material. A "PVC" liner almost certainly has additives (plasticizers, etc.) in order to attain other necessary characteristics such as flexibility. These additives do not have the same resistance as PVC. The liner may be attacked by the chemical contents, resulting in a breakdown of the sheet material and adhesive or other material used to join sheets of the lining. It should also be considered for its chemical resistance, and should be required to meet the same standards as the lining material.

It is difficult to know the exact composition of the liner material since there are no standard labeling procedures. Since only a few lining materials, such as SCHLEGEL sheet (polyethylene) are free from additives subject to attack, it is necessary to find out the composition of and test the lining under consideration with the chemicals to be contained.

The contents

Few sites are constructed to contain a single discrete chemical. Commonly, there is a combination of chemicals that interact with one another and may result in a change in the make-up of the contents. When considering liners, therefore, it is necessary to take into account the most severe conditions expected to exist.

Factors to consider are:

- Chemicals that may result from chemical reactions in the basin.
- The concentrations of each chemical to be contained.
- The highest temperature expected in the basin contents (since high temperatures accelerate chemical attack).

Again, if all of these factors cannot be known with certainty it is advisable to test all lining materials under consideration prior to selecting one.

On the reverse side we have provided a simple but comprehensive test procedure to follow in order to test potential liner materials. Or if you prefer, Schlegel Lining Technology laboratory personnel will be happy to conduct this comparative test for you. Tests are done according to this standard procedure and are documented fully for your assurance of reproducibility. Just contact your Schlegel Lining Technology representative to receive assistance or additional information.

General Chemical Resistance Guidelines

X = Generally Good Resistance	Butyl Rubber		Chlorinated Polyethylene (CPE)		Chloro-sulfonated Polyethylene (CSPE)		Elasticized Polyolefin		Ethylene Propylene Diene Monomer (EPDM)		Poly-chloroprene (Neoprene)		Polyethylene		Polyvinyl Chloride (PVC)	
	100°F	158°F	100°F	158°F	100°F	158°F	100°F	158°F	100°F	158°F	100°F	158°F	100°F	158°F	100°F	158°F
Aliphatic Hydrocarbons			X	X			X				X	X	X	X		
Aromatic Hydrocarbons							X				X	X	X	X		
Chlorinated Solvents	X	X					X		X		X		X	X		
Oxygenated Solvents	X	X					X		X	X	X	X	X	X		
Crude Petroleum Products			X	X			X				X	X	X	X		
Alcohols	X	X	X	X			X		X	X	X	X	X	X	X	X
Acids:																
Organic	X	X	X	X	X		X		X	X	X	X	X	X	X	X
Inorganic	X	X	X	X	X		X		X	X	X	X	X	X	X	X
Bases:																
Organic	X	X	X	X	X		X		X	X	X	X	X	X	X	X
Inorganic	X	X	X	X	X		X		X	X	X	X	X	X	X	X
Heavy Metals	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Salts	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X

Schlegel® Chemical Resistance

Abbreviations

S = Satisfactory
L = Limited application possible
U = Unsatisfactory
— = Not tested

Concentration
sat. sol. = Saturated aqueous solution, prepared at 20°C (68°F)
sol. = aqueous solution with concentration above 10% but below saturation level
dil. sol. = diluted aqueous solution with concentration below 10%
cust. conc. = customary service concentration

Chemical Resistance Table.

Shown here are the results of tests reported by the supplier of high density polyethylene granulate used to manufacture Schlegel® sheet. The high density polyethylene is resistant to the chemicals listed. The degree of chemical attack on any material is influenced by a number of variable factors and their interaction, including temperature, pressure, size of area under attack, exposure duration, and the like. Where sheet will be exposed to a mixture of chemicals it is recommended that tests be carried out for sheet resistance to that chemical mixture. Therefore, these ratings are offered as a guide only.

Medium	Concentration	Resistance at 20°C (68°F)	Resistance at 60°C (140°F)
A			
Acetic acid	100%	S	L
Acetic acid	10%	S	S
Acetic acid anhydride	100%	S	L
Acetone	100%	L	L
Adipic acid	sat. sol	S	S
Allyl alcohol	96%	S	S
Aluminum chloride	sat. sol.	S	S
Aluminum fluoride	sat. sol.	S	S
Aluminum sulfate	sat. sol.	S	S
Alums	sol.	S	S
Ammonia, aqueous	dil. sol.	S	S
Ammonia, gaseous dry	100%	S	S
Ammonia, liquid	100%	S	S
Ammonium chloride	sat. sol.	S	S
Ammonium fluoride	sol.	S	S
Ammonium nitrate	sat. sol.	S	S
Ammonium sulfate	sat. sol	S	S
Ammonium sulfide	sol.	S	S
Amyl acetate	100%	S	L
Amyl alcohol	100%	S	L
Aniline	100%	S	L
Antimony trichloride	90%	S	S
Arsenic acid	sat. sol.	S	S
Aqua regia	HCl-HNO_3 3/1	U	U
B			
Barium carbonate	sat. sol.	S	S
Barium chloride	sat. sol.	S	S
Barium hydroxide	sat. sol.	S	S
Barium sulfate	sat. sol	S	S
Barium sulfide	sol.	S	S
Benzaldehyde	100%	S	L
Benzene	—	L	L
Benzoic acid	sat. sol.	S	S
Beer	—	S	S
Borax	sat. sol.	S	S
Boric acid	sat. sol	S	S
Bromine, gaseous dry	100%	U	U
Bromine, liquid	100%	U	U
Butane, gaseous	100%	S	S
Butanol	100%	S	S
Butyric acid	100%	S	L
C			
Calcium carbonate	sat. sol.	S	S
Calcium chlorate	sat. sol.	S	S
Calcium chloride	sat. sol.	S	S
Calcium hydroxide	sat. sol.	S	S
Calcium hypochlorite	sol.	S	S
Calcium nitrate	sat. sol.	S	S
Calcium sulfate	sat. sol.	S	S
Calcium sulfide	dil. sol.	L	L
Carbon dioxide, gaseous dry	100%	S	S
Carbon disulfide	100%	L	U
Carbon monoxide	100%	S	S
Chloracetic acid	sol.	S	S
Carbon tetrachloride	100%	L	U
Chlorine, aqueous solution	sat. sol	L	U
Chlorine, gaseous dry	100%	L	U
Chloroform	100%	U	U
Chromic acid	20%	S	L
Chromic acid	50%	S	L
Citric acid	sat. sol.	S	S
Copper chloride	sat. sol	S	S
Copper nitrate	sat. sol	S	S
Copper sulphate	sat. sol	S	S
Cresylic acid	sat. sol	L	—
Cyclohexanol	100%	S	S
Cyclohexanone	100%	S	L
D			
Decahydronaphthalene	100%	S	L
Dextrine	sol	S	S
Diethyl ether	100%	L	—
Dioctylphthalate	100%	S	L
Dioxane	100%	S	S
E			
Ethane diol	100%	S	S
Ethanol	40%	S	L
Ethyl acetate	100%	S	U
Ethylene trichloride	100%	U	U
F			
Ferric chloride	sat. sol.	S	S
Ferric nitrate	sol.	S	S
Ferric sulfate	sat. sol.	S	S
Ferrous chloride	sat. sol	S	S
Ferrous sulfate	sat. sol	S	S
Fluorine, gaseous	100%	U	U
Fluosilicic acid	40%	S	S
Formaldehyde	40%	S	S
Formic acid	50%	S	S
Formic acid	98-100%	S	S
Furfuryl alcohol	100%	S	L
G			
Gasolene	—	S	L
Glacial acetic acid	96%	S	L
Glucose	sat. sol.	S	S
Glycerine	100%	S	S
Glycol	sol.	S	S
H			
Heptane	100%	S	U
Hydrochloric acid	10%	S	S
Hydrobromic acid	50%	S	S
Hydrobromic acid	100%	S	S
Hydrochloric acid	10%	S	S
Hydrochloric acid	concentrated	S	S
Hydrocyanic acid	10%	S	S
Hydrofluoric acid	60%	S	L
Hydrofluoric acid	4%	S	S
Hydrogen	100%	S	S

Medium	Concentration	Resistance at 20°C (68°F)	Resistance at 60°C (140°F)
Hydrogen peroxide	30%	S	S
Hydrogen peroxide	90%	S	U
Hydrogen sulfide, gaseous	100%	S	S
L			
Lactic acid	100%	S	S
Lead acetate	sat. sol	S	—
M			
Magnesium carbonate	sat. sol	S	S
Magnesium chloride	sat. sol	S	S
Magnesium hydroxide	sat. sol	S	S
Magnesium nitrate	sat. sol	S	S
Maleic acid	sat. sol	S	S
Mercury	100%	S	S
Mercuric chloride	sat. sol	S	S
Mercuric cyanide	sat. sol	S	S
Mercuric nitrate	sol	S	S
Methanol	100%	S	S
Methylene chloride	100%	L	—
Milk	—	S	S
Molasses	cust. conc	S	S
N			
Nickel chloride	sat. sol	S	S
Nickel nitrate	sat. sol	S	S
Nickel sulfate	sat. sol	S	S
Nicotinic acid	dil. sol	S	—
Nitric acid	25%	S	S
Nitric acid	50%	S	U
Nitric acid	75%	U	U
Nitric acid	100%	U	U
O			
Oils and Grease	—	S	L
Oleic acid	100%	S	L
Orthophosphoric acid	50%	S	S
Orthophosphoric acid	95%	S	L
Oxalic acid	sat. sol	S	S
Oxygen	100%	S	L
Ozone	100%	L	U
P			
Petroleum	—	S	L
Phenol	sol	S	S
Phosphorus trichloride	100%	S	L
Photographic developer	cust. conc	S	S
Picric acid	sat. sol	S	—
Potassium bicarbonate	sat. sol	S	S
Potassium bisulfate	sat. sol	S	S
Potassium bisulfide	sol	S	S
Potassium bromate	sat. sol	S	S
Potassium bromide	sat. sol	S	S
Potassium carbonate	sat. sol	S	S
Potassium chlorate	sat. sol	S	S
Potassium chloride	sat. sol	S	S
Potassium chromate	sat. sol	S	S
Potassium cyanide	sol	S	S
Potassium dichromate	sat. sol	S	S
Potassium ferricyandide	sat. sol	S	S
Potassium ferrocyanide	sat. sol	S	S
Potassium fluoride	sat. sol	S	S
Potassium hydroxide	10%	S	S
Potassium hydroxide	sol	S	S
Potassium hypochloride	sol	S	L
Potassium nitrate	sat. sol	S	S
Potassium orthophosphate	sat. sol	S	S
Potassium perchlorate	sat. sol	S	S
Potassium permanganate	20%	S	S
Potassium persulfate	sat. sol	S	S
Potassium sulfate	sat. sol	S	S
Potassium sulfite	sol	S	S
Propionic acid	50%	S	S
Propionic acid	100%	S	L
Pyridine	100%	S	L
Q			
Quinol (Hydroquinone)	sat. sol	S	S

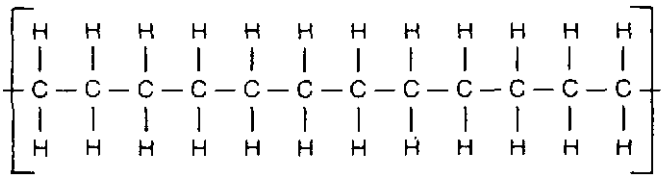
Medium	Concentration	Resistance at 20°C (68°F)	Resistance at 60°C (140°F)
S			
Salicylic acid	sat. sol	S	S
Silver acetate	sat. sol	S	S
Silver cyanide	sat. sol	S	S
Silver nitrate	sat. sol.	S	S
Sodium benzoate	sat. sol.	S	S
Sodium bicarbonate	sat. sol	S	S
Sodium biphosphate	sat. sol	S	S
Sodium bisulfite	sol	S	S
Sodium bromide	sat. sol	S	S
Sodium carbonate	sat. sol	S	S
Sodium chlorate	sat. sol	S	S
Sodium chloride	sat. sol	S	S
Sodium cyanide	sat. sol	S	S
Sodium ferricyanide	sat. sol	S	S
Sodium ferrocyanide	sat. sol.	S	S
Sodium fluoride	sat. sol	S	S
Sodium fluoride	sat. sol	S	S
Sodium hydroxide	40%	S	S
Sodium hydroxide	sat. sol	S	S
Sodium hypochloride	15% active chlorine	S	S
Sodium nitrate	sat. sol	S	S
Sodium nitrite	sat. sol	S	S
Sodium orthophosphate	sat. sol	S	S
Sodium sulfate	sat. sol	S	S
Sodium sulfide	sat. sol	S	S
Sulfur dioxide, dry	100%	S	S
Sulfur trioxide	100%	U	U
Sulfuric acid	10%	S	S
Sulfuric acid	50%	S	S
Sulfuric acid	98%	S	U
Sulfuric acid	fuming	U	U
Sulfurous acid	30%	S	S
T			
Tannic acid	sol	S	S
Tartaric acid	sol	S	S
Thionyl chloride	100%	L	U
Toluene	100%	L	U
Triethylamine	sol	S	L
U			
Urea	sol	S	S
Urine	—	S	S
W			
Water	—	S	S
Wine vinegar	—	S	S
Wines and liquors	—	S	S
X			
Xylene	100%	L	L
Y			
Yeast	sol	S	S
Z			
Zinc carbonate	sat. sol	S	S
Zinc chloride	sat. sol	S	S
Zinc (II) chloride	sat. sol	S	S
Zinc (IV) chloride	sat. sol	S	S
Zinc oxide	sat. sol	S	S
Zinc sulfate	sat. sol.	S	S

Specific immersion testing should be undertaken to ascertain the suitability of chemicals not listed above with reference to special requirements.

In general, technical specifications for a plastic resin or plastic product can be divided into three areas:
1) Specifications which serve to characterize a given resin in general, i.e., identify it with regard to other resins;
2) Specifications concerning a resin's processibility. These concentrate on the properties of the material in the molten state as it is found in processing;
3) Specifications concerning application suitability. These give an evaluation of the material's suitability in product form under particular stressing modes found in field conditions (the individual application).

Characterization
Specifications such as density and mean molecular weight serve to identify a given polyethylene resin. In addition, they are important as indexes of the material's structure; thus any changes in these values will be accompanied by changes in processing and application properties.

Processibility
In processing, the important properties are those of the molten resin as it is processed as a melt to product form. The processibility of a thermoplastic resin is characterized by properties such as melting point (or melting point range) and melt index. Further important properties here are the susceptibility to melt fracture and thermal stability.



Polyethylene: Chemical Structure

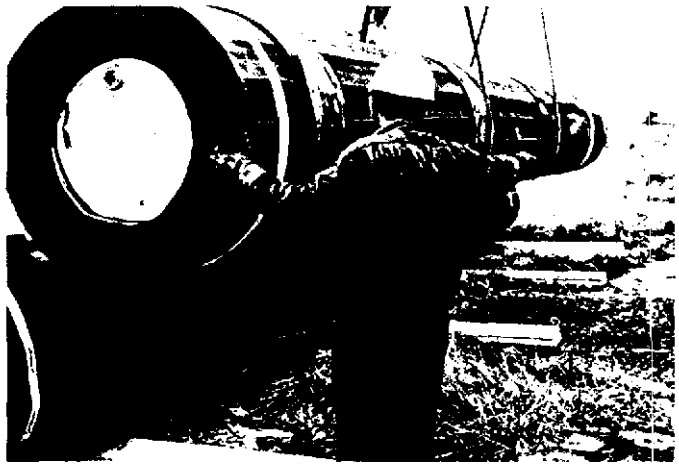
Application Suitability
A material's suitability is evaluated by comparing the stress expected in the specific application to the properties determined in material testing.

Forms of attack to the sheet include:

- physical stressing
- aggressive chemicals
- ultraviolet degradation
- high temperatures
- biological attack

An extensive range of material properties can be used to evaluate performance under these forms of attack, including:

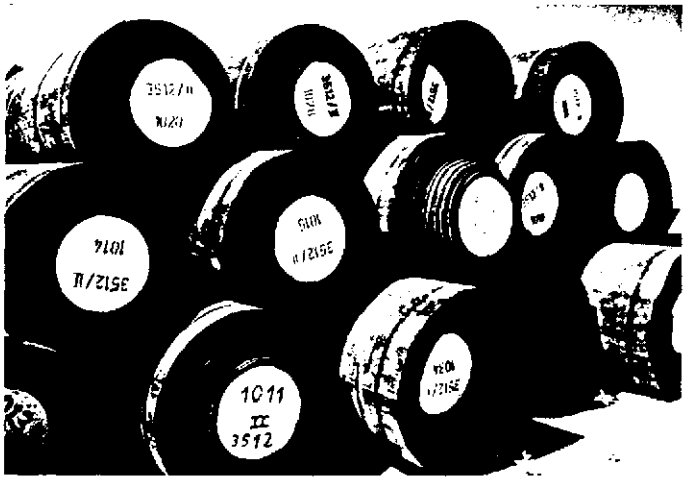
- strength properties (tensile, flexural, compressive, shear, etc.)
- deformation and relaxation behavior
- chemical resistance
- stress crack resistance
- weathering resistance
- thermal stability
- resistance to rodents, termites, root penetration, and microbiological attacks.



Physical Properties

Raw Material
One of the standard raw materials used for **Schlegel®** sheet is high density polyethylene. Lower and medium range resins are also processed by Schlegel Lining Technology, Inc.

This high density polyethylene has a relatively high molecular weight and a narrow molecular weight distribution. It contains a 2% carbon black component as stabilization against UV attack. Plasticizer loss, a problem for many other thermoplastic materials, is not a problem for **Schlegel** sheet as HDPE does not contain plasticizers, or other chemical additives.



This high density polyethylene has a low degree of crystallinity which accounts for its excellent deformation and stress crack properties. Its high flexibility is retained at extremely low temperatures. It has the wide chemical resistance spectrum typical of high density polyethylene resins.

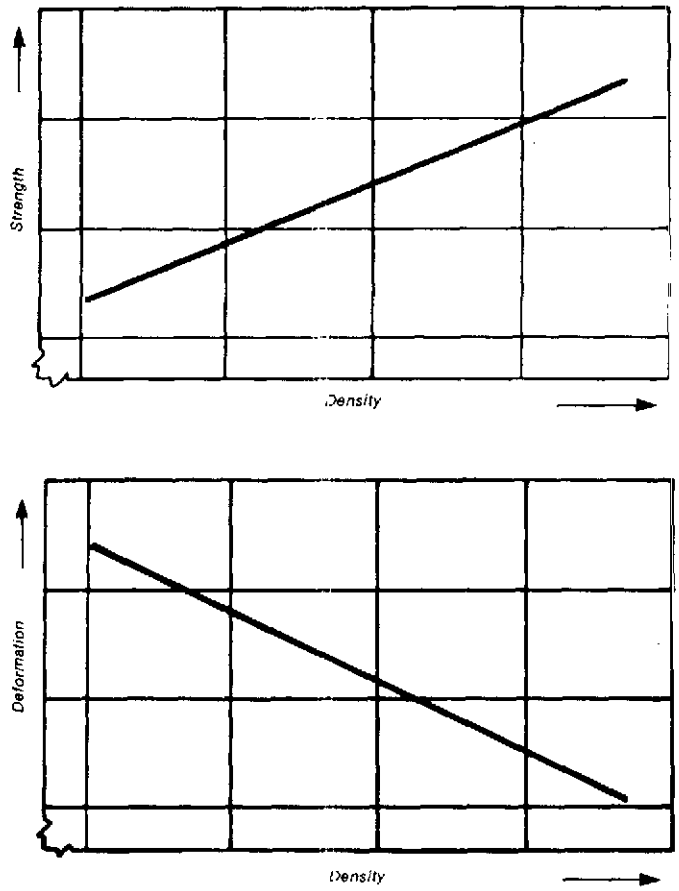
This resin is also used in many other industrial applications requiring high flexibility and toughness, including pipeline construction, chemical process components, construction, and foodstuffs packaging.

Density
The density of a polyethylene gives a very exact indication of the degree of crystallinity and thus an index of the mechanical properties, including those in aggressive media. For example, an increase in density will be accompanied by an increase in tensile strength. On the other hand, the increased density will also cause decreased deformation values. Thus the density must be kept within certain limits to ensure constant product quality. The density of the base resin for **Schlegel®** sheet is guaranteed within a narrow tolerance range as required for maintenance of constant mechanical properties.

Melt Index (MFI)
The melt index is primarily a measure of a material's viscosity in the molten state. It gives the rate of extrusion of a molten resin through a die of specified length and diameter under prescribed conditions of temperature and piston load. It gives an indication of a material's mean molecular weight (chain length) and flow properties.

The melt index of the processed sheet material is not significantly different from the raw material. Spot checks have shown that the sheet melt index is roughly equal to the raw material melt index, an indication that no thermal damage has occurred during the production process.

Average Molecular Weight
The relative solute viscosity indicates a plastic's mean molecular weight and thus the degree of polymerization. Specifications for the HDPE used for **Schlegel** sheet include a mean molecular weight of 150,000. Significant deviations from this mean molecular weight would lead to altered physical properties.

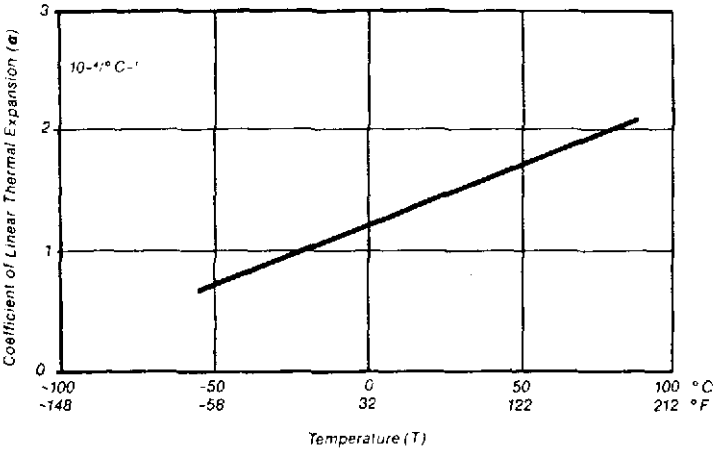


Typical physical properties of middle- to high-density polyethylene shown as a function of density.

Coefficient of Linear Thermal Expansion

The coefficient of linear thermal expansion is defined as the fractional change in length over a given temperature interval. This coefficient varies with temperature as shown in the illustration. The value given in the Physical Properties Table of $2 \times 10^{-4}/°C^{-1}$ is as measured at 80°C. The average value between -30°C and +30°C as specified in ASTM D 696 is $1.2 \times 10^{-4}/°C^{-1}$.

Polymeric materials have relatively high coefficients of thermal expansion as compared to other construction materials. This must be kept in mind in planning design and installation as well as in subsequent operation.



Coefficient of linear thermal expansion (α) vs temperature (T).

Water Absorption

Water absorption in polyethylene is relatively low due to the extreme differences in polarity between the substances. The U.S. standard for water absorption of plastic materials is ASTM D 570. The water absorption of **Schlegel®** sheet according to this test procedure is 0.085% for 4 days exposure. This is negligible considering the experimental error present in normal analytical testing.

Surface Hardness (Ball Indentation Hardness)
Surface hardness is a measure of a material's strength; it does not, however, give an evaluation of behavior under field stressing modes. It is simply a value which can be used to compare various materials in a quantitative manner.

Notched Impact Strength
The notched impact strength of a material gives an indication of its deformation behavior under sudden high speed loading. This test is a relatively simple method of determining a plastic's glass transition temperature, the temperature below which brittle fracture occurs. For **Schlegel**® sheet, this temperature is lower than -75° C, the lowest temperature tested.

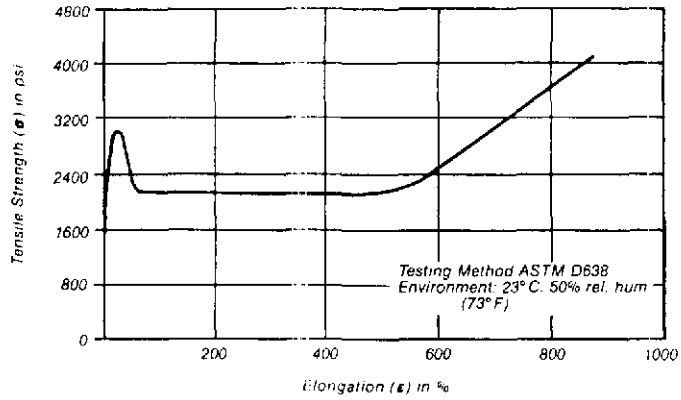
Tensile Properties
Short-term one-dimensional tensile testing is a simple, proven method of determining several important properties in order to predict a liner's field behavior. The tensile behavior of an HDPE material can be characterized by evaluating the following five properties:

- Elongation at Yield
- Yield Strength
- Elongation at Break
- Ultimate Tensile Stress
- Modulus of Elasticity

The tensile properties (in particular the elongation values) depend on the cross head speed, specimen dimensions, and method of extension measurement used in the testing. The accepted U.S. testing standard (ASTM D 638) provides for several different specimen dimensions and cross head speeds. The values given in the specifications correspond to Specimen Type IV and Speed C in the ASTM standard.

In Schlegel's routine quality control testing, the extension is determined over the entire narrow length of the specimen and must be corrected by a factor of 1.25 or 1.33 (depending on the specimen size) to give the actual local deformation.

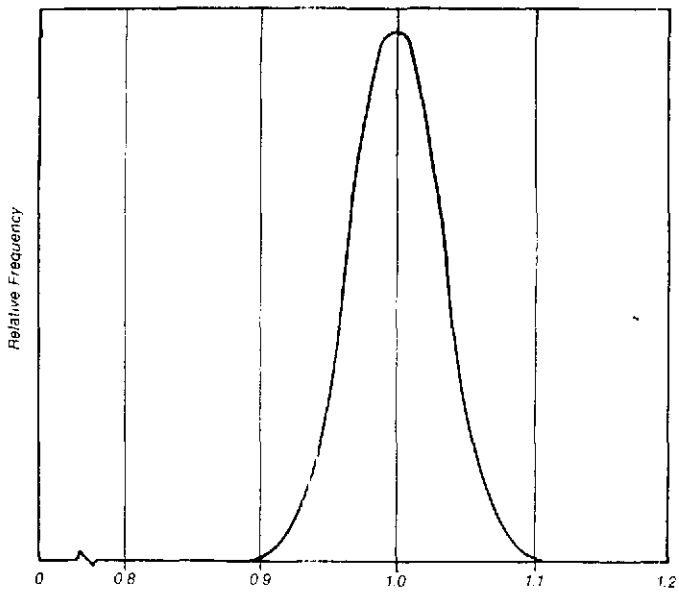
One tensile property in particular is often used to describe a material's strength. This is the modulus of elasticity, defined as the slope of the stress-strain plot in the linear (Hookian) zone. The value given in the specifications is the slope for low stresses, where a straight line is approximated. These are the loading conditions almost exclusively encountered in field applications.



Typical stress-strain curve.

Thickness
The latest guidelines from the IfBT (Institute for Construction Technology in Berlin, West Germany) drafted specially for plastic earth basin liners specify permissible deviations from the nominal thickness of ±15%.

Extensive thickness measurements of **Schlegel** sheet have shown a typical thickness deviation of not more than ±10%.



Typical sheet thickness relative to nominal thickness (t_n).

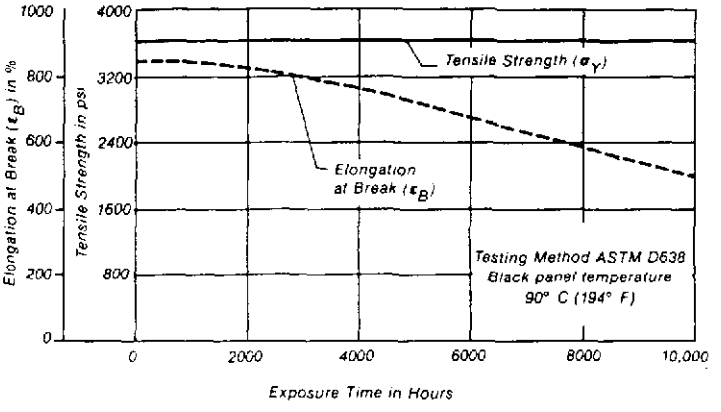
Weathering Resistance

Weathering attack to a polymeric material can be defined as changes in certain material properties due to the effect of the field environment. In general, two types of attack are prevalent: UV attack and thermal oxidation attack.

The resistance to UV attack is determined in the Xenon Test 450 according to the German standard DIN 53 387. This is a simulation of sunlight using a special light source with high ultraviolet components. At an ambient temperature of 25°C, a black panel temperature of 31°C and a relative humidity of 65%, **Schlegel®** sheet samples showed no change in mechanical properties. This test period corresponds to roughly 25 years under middle northern hemisphere climatic conditions.

Testing of **Schlegel** sheet's thermal oxidation resistance at a constant temperature of 50°C gives an extrapolated service life (i.e. exposure period over which no significant decrease in physical properties occurs) of more than 50 years.

Combined UV and thermal oxidation resistance testing (Xenon Test at an ambient temperature of 80-90°C) resulted in no significant change in tensile properties up to the yield point after 10,000 hours. This can be seen by the yield strength vs. exposure time curve in the illustration. Although a decrease in the elongation at break had occurred over the exposure period, this is not important from an application standpoint as stresses found in field conditions are almost exclusively below the yield point.

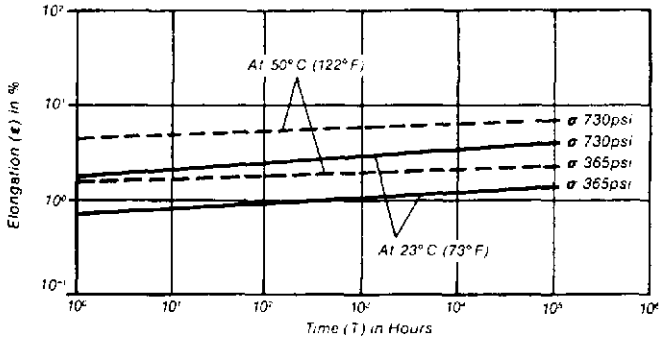


Typical tensile strength vs time at high temperature.

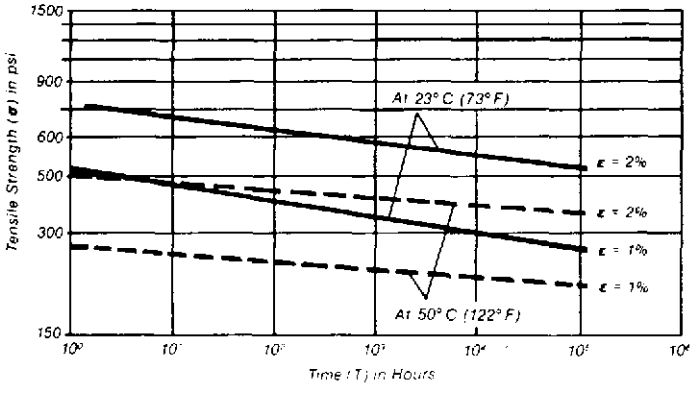
Typical Physical Properties of SCHLEGEL® Sheet

Property	Symbol	Test Method	Value	Units
Density	D	ASTM D 792 Method B	0.95 0.95	g/cm³
Melt Flow Rate	F/T	ASTM D 1238 Condition E	0.2	g/10 min
Average Molecular Weight	$\overline{M}$	ASTM D 2857	1.5 x 10⁵	— —
Coefficient of Linear Thermal Expansion	α	ASTM D 696	1.2 x 10⁻⁴	°C⁻¹
Water Absorption	ΔW	ASTM D 570	0.085	%/4 days
Shore D Hardness	H	ASTM D 2240	65	Shore D
Impact Resistance Notched	E_J	ASTM D 256 Method B	No brea-	ft. lb/inch of Notch
Percentage Elongation at Yield	ε_Y	ASTM D 638 Speed C Test Specimen Type IV	15	%
Percentage Elongation at Break	ε_B		800	%
Tensile Stress at Yield	σ_Y		2,800	psi
Tensile Strength at Break	σ_B		3,500	psi
Thickness	t	ASTM D 374	0.10 (2.5	in (mm)

Schlegel® Long Term Physical Properties



Typical deformation (ε) vs time (T) under constant load (σ).



Typical tensile stress (ε) vs time (T) under constant load (σ).

Long Term Physical Properties

The long term physical properties of thermoplastic materials can be tested in two types of physical testing:

- creep testing
- relaxation testing

Creep Behavior

In creep testing, a specimen is subjected to a constant nominal stress and the deformation determined as a function of time. The rate of deformation will increase for increased stress and/or increased test temperature.

Relaxation Behavior

In relaxation testing, a specimen is subjected to a constant deformation and the stress is determined as a function of time. If the deformation is small enough or the relaxation time long enough, relaxation will be complete, i.e. the specimen will return to the unstressed state.

Both types of long-term stressing are found in field applications of plastic liners. Although the behavior of **Schlegel®** sheet under these types of stressing has been determined in laboratory testing as shown in the adjacent diagrams, this data cannot be used for dimensioning calculations as the exact stress levels present in field applications are generally not available.

Temperature Dependence of Physical Properties

Elevated temperatures will generally cause reduced strength and increased elongation values in polymeric materials.

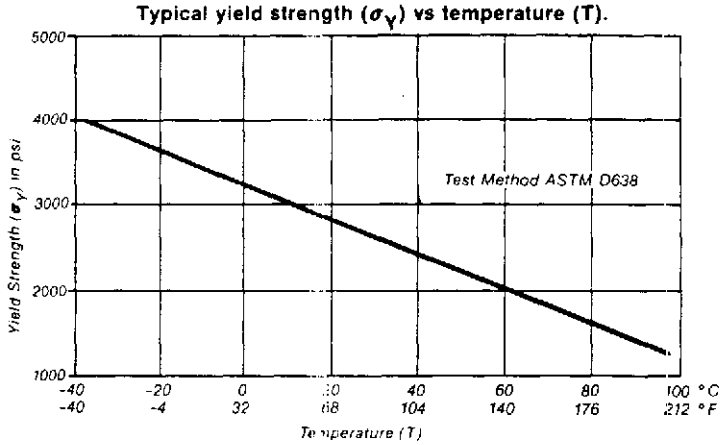
Strength

The yield strength vs temperature curve is typical in that the strength decreases with increasing temperature. The decrease occurs gradually over the tested temperature range of -40° C to 80° C. Even at 80° C, the value of the yield strength is more than 25% of the yield strength at 20° C. The yield strength at 80° C is nonetheless on the same order of magnitude as low density polyethylene and other synthetic liner materials at normal temperatures.

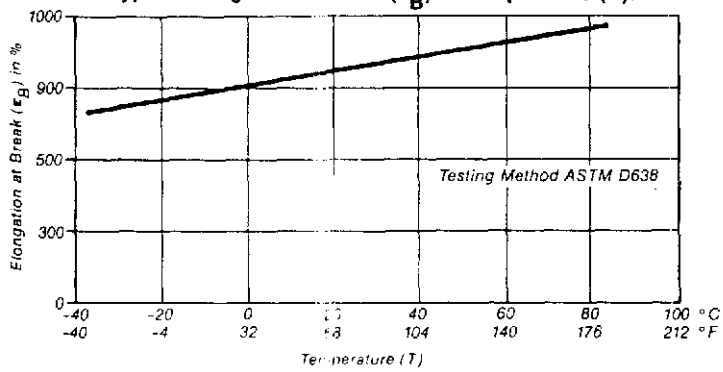
Deformation

As can be seen in the elongation at break vs temperature curve shown, the elongation at break under uniaxial stress is higher at elevated temperatures, as is the case for all thermoplastics. The temperature dependence of the elongation at yield is similar to this function. Of particular interest for lining applications is the fact that the elongation at break is still extremely high at -40° C.

Typical yield strength (σ_Y) vs temperature (T).



Typical elongation at break (ε_B) vs temperature (T).



Resistance to Rodents, Termites, Root Penetration and Microbiological Attack

Biological factors can be as dangerous to a synthetic liner as other forms of attack. This would include rodent gnawing, termite attack, fungus growth and root penetration.

Rodents

Testing carried out for a hydraulic engineering project showed that the wild rats used in the testing could not break through an enclosure constructed of **Schlegel®** sheet, even if otherwise faced with starvation.

Termites

Termite resistance testing performed by independent testing laboratories showed favorable results for **Schlegel** sheet. As in the rodent testing, the animals were unable to damage the **Schlegel** sheet specimen beyond light surface scratches, even with no other possible source of nutrition available. The experiments were all conducted in a siege situation to death.

Microbiological Attack

Soil burial testing conducted by independent testing laboratories has shown no detectable decrease in physical properties of **Schlegel** sheet after soil exposure. The tests were conducted over periods of up to two years. The high performance of the sheet is possible because there are no plasticizers or other migrating materials in **Schlegel** sheet.

Root Penetration

In root penetration testing on **Schlegel** sheet, lupines were planted over a sheet specimen and allowed to grow for a six-week period. At the end of the test period, no root penetration or indentation had occurred, although a bitumen slab exposed to the same conditions was penetrated at numerous points by the roots.

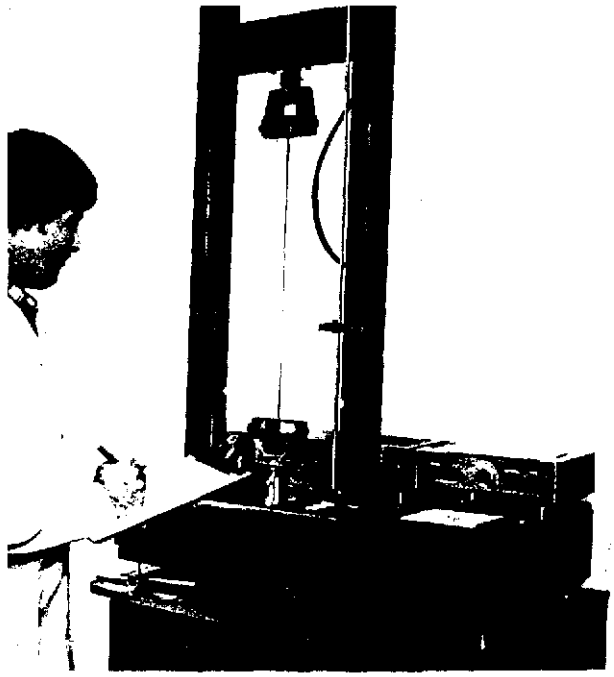
Quality Control

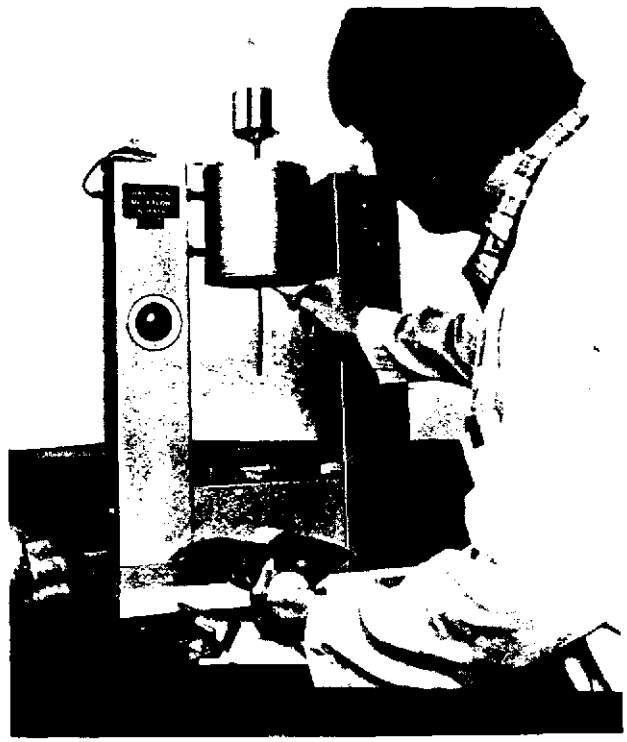
Schlegel® sheet is manufactured to strict quality control specifications. Comprehensive testing throughout the entire sequence from raw material to finished product ensures the high quality standards required in synthetic liner applications.

Incoming raw material is tested by both the supplier and the Schlegel laboratory to ensure that specifications for density, molecular weight, melt index and percent volatile components are met. Every incoming material lot is tested. Sheet extrusion is carefully supervised, with continuous inspection of all key variables including process temperatures, extruder throughput, manufacturing speed and sheet thickness.

The final stage of quality control is inspection of all extrusion welded joints. This consists of ultrasonic non-destructive testing of all overlap welds in conjunction with other testing procedures.

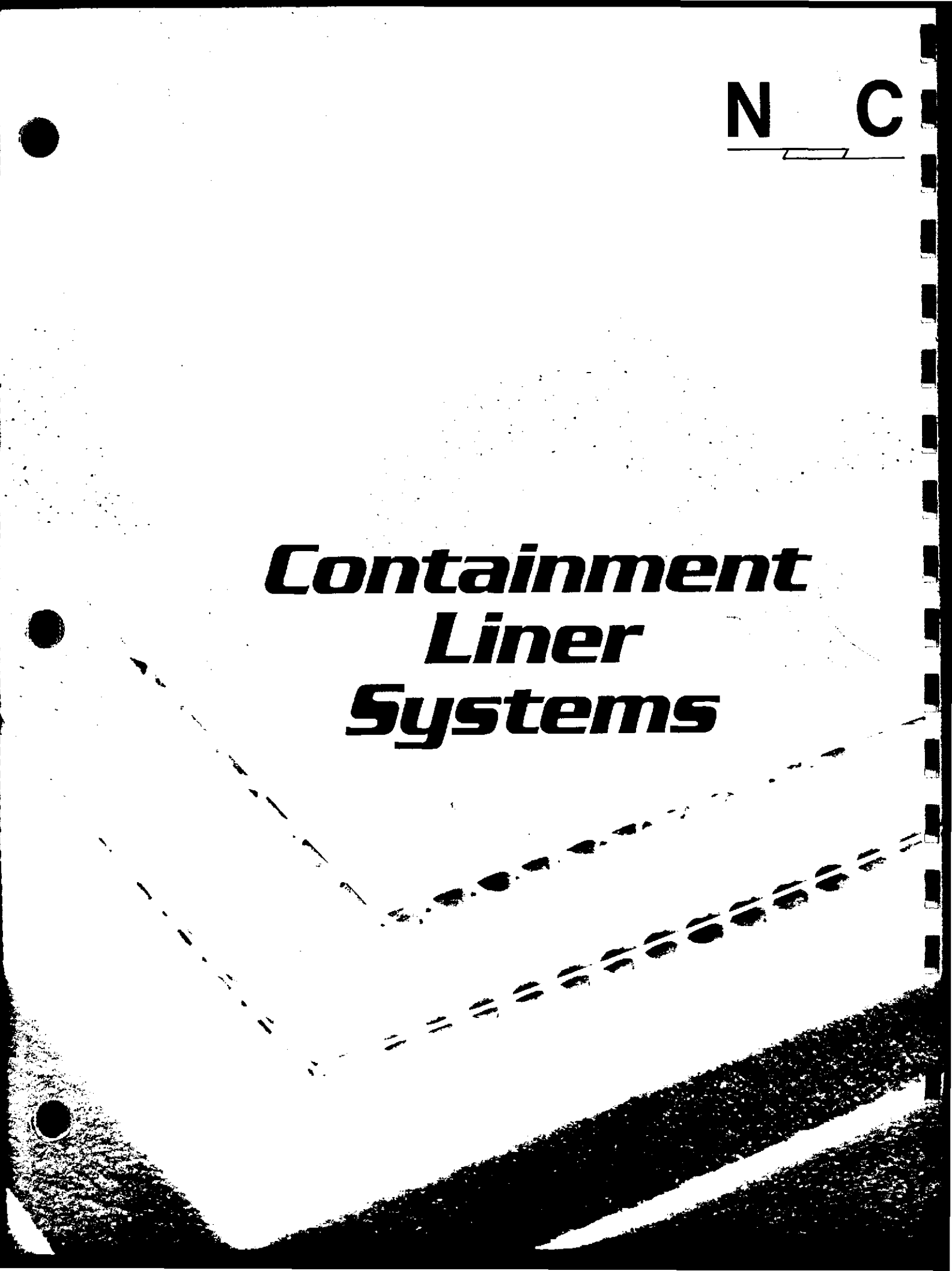
Various forms of destructive testing are used on a random sample basis for additional security: weld samples are cut out of the liner and stressed to failure, both directly at the site and in Schlegel's laboratory. A complete site testing report is filled out by the testing technician, documenting the quality of the installed joint.





N C

Containment Liner Systems



National Seal Company offers a full line of flexible membrane liners

National Seal Company offers a full line of flexible membrane liners, drainage netting and geotextiles:

Geomembranes:

National Seal Company recently installed the world's largest flat sheet extruder for making HDPE geomembranes. On our sophisticated, computer monitored and controlled extrusion line we are able to produce geomembranes up to 15 feet wide in any thickness between 40 and 100 mils. And, our ±3% typical variation on thickness is far superior to the industry standard 10% tolerance.

Our geomembranes are made of the highest quality, virgin resin. From this resin we produce an extremely strong, durable and chemically resistant liner. As a testament to its durability, HDPE geomembrane is the material of choice for use in hazardous waste disposal sites.

Drainage netting:

National Seal Company also manufactures Poly-Net® — a drainage netting made of the same durable resin as our flexible membrane liner. Because of the identity of the resins used for the geomembrane and the drainage netting, you will always be assured that the geomembrane and netting supplied by National Seal Company are chemically compatible.

We make Poly-Net by extruding strands of polyethylene into a diamond shaped net. This three dimensional structure has great strength and very high transmissivity even under high compressive loads.

Geotextiles:

It often happens that a layer of geotextile is added to a design to act as a filter for drainage netting or to act as a protective cushion underneath or above a geomembrane. Geotextile can effectively increase the puncture resistance of the liner system and can reduce the potential for geomembrane abrasion. The geotextile can also act as a pathway for escaping gas. Whenever your application calls for the use of a geotextile, we can supply you with material manufactured to the same high standard of quality applicable to all NSC's products.

NSC

RECOMMENDED THICKNESS SPECIFICATIONS

FOR

GEOSYNTHETIC INSTALLATIONS

With our computer controlled flat sheet die extrusion process, we are able to maintain minimum average roll thicknesses in accordance with your specifications. National Seal Company recommends use of the following specifications.

SPECIFIED THICKNESS	MINIMUM AVERAGE ROLL VALUE	LOWEST INDIVIDUAL THICKNESS ALLOWED
40 mil	40 mil	38 mil
60 mil	60 mil	57 mil
80 mil	80 mil	76 mil
100 mil	100 mil	95 mil

Thickness shall be measured in accordance with ASTM D 751. The minimum average roll thickness shall be as specified with no individual thickness measurement on the sheet falling more than 5% below the specified value.

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NSC

NATIONAL SEAL COMPANY
ROLLSTOCK SPECIFICATIONS

I. RESIN SPECIFICATION:

Each lot of resin will be analyzed by National Seal Company's Laboratory as follows:

SPECIFICATION	TEST METHOD
Density	ASTM D 1505
Carbon Black Content	ASTM D 1603
Melt Flow Index	ASTM D 1238
Moisture Content	

II. SHEET SPECIFICATION:

Gauge	±5%
Width	15.0'
Carbon Black	2% to 3%
Appearance	Smooth surface, minimal haze.

III. QUALITY ASSURANCE and TESTING:

1. Sheet appearance will be monitored continuously by production personnel and at least once per hour by a member of our Laboratory.

2. Sheet thickness will be continuously monitored by automatic gauging equipment located on the extruder.

3. Production will hold sheet thickness to within ±3% whenever possible. ±5% is our advertised tolerance.

4. National Seal Company's Laboratory will perform the following tests every 10,000 pounds of material produced:

SPECIFICATION	TEST METHOD
Tensile Properties	ASTM D 638
Carbon Black Dispersion	ASTM D 3015
Thickness	ASTM D 751
Dimensional Stability	ASTM D 1204

See National Seal Company's Quality Control Manual for a full listing of the tests which our Laboratory can perform. Please contact your sales representative for pricing.

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ENVIROSEAL™ HDPE GEOMEMBRANE

National Seal Company's *ENVIROSEAL* geomembranes are extruded using domestic, virgin, first-quality, high molecular weight, polyethylene resin and are manufactured specifically for the purpose of containment in hydraulic structures. The HDPE compound used in *ENVIROSEAL* geomembranes has been formulated to be chemically resistant, free of leachable additives and resistant to ultraviolet degradation.

40 MIL PHYSICAL PROPERTIES

ALL PROPERTIES MEET OR EXCEED NSF STANDARD 54 SPECIFICATIONS FOR HDPE

PROPERTY	MINIMUM AVERAGE ROLL VALUES (unless otherwise indicated)			
	English		Metric	
	Units	Value	Units	Value
THICKNESS, ASTM D 751, NSF Mod., Nominal	mils	40.0	mm	1.016
Minimum Average	mils	38.8	mm	0.986
Lowest Individual Reading	mils	38.0	mm	0.965
DENSITY, ASTM D 1505			g/cm^3	0.94
MELT FLOW INDEX, ASTM D 1238, Cond. E, Max.			*g/10 min*	1.0
CARBON BLACK CONTENT, ASTM D 1603	percent	2 to 3	percent	2 to 3
CARBON BLACK DISPERSION, ASTM D 3015	rating	A1 or A2	rating	A1 or A2
MINIMUM TENSILE PROPERTIES, ASTM D 638, NSF Mod.				
Stress at Yield	psi	2200	MPa	15.2
	ppi	88	kg/cm	15.8
Stress at Break	psi	3800	MPa	26.2
	ppi	152	kg/cm	27.2
Strain at Yield	percent	13	percent	13
Strain at Break	percent	600	percent	600
TEAR RESISTANCE, ASTM D1004	ppi	700	kg/cm	125
	lbs	28	kg	12.7
PUNCTURE RESISTANCE, FTMS 101, 2065	ppi	1300	kg/cm	233
	lbs	52	kg	23.6
BRITTLENESS TEMP, ASTM D 746 B, Pass	°F	-103	°C	-75
ESCR, ASTM D 1693, NSF Mod., Pass	hours	1500	hours	1500
DIMENSIONAL STABILITY, ASTM D1204, NSF Mod, Max.	percent	2.0	percent	2.0

NATIONAL SEAL SEAMING PROPERTIES

(All NSC seams will demonstrate a Film Tearing Bond in Peel and Shear)

SHEAR STRENGTH, ASTM D 4437, NSF Mod.	psi	2000	MPa	13.8
	ppi	80	kg/cm	14.3
PEEL ADHESION, ASTM D 4437, NSF Mod.	psi	1500	MPa	10.3
(hot wedge fusion weld)	ppi	60	kg/cm	10.7
PEEL ADHESION, ASTM D 4437, NSF Mod.	psi	1300	MPa	8.97
(fillet extrusion weld)	ppi	52	kg/cm	9.31

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NSC NATIONAL SEAL COMPANY

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Aurora, Illinois 60504
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FAX: 708-898-2567

ENVIROSEAL™ HDPE GEOMEMBRANE

The following data is provided for informational purposes only and is not intended as a specification, warranty or guarantee. National Seal Company does not generally perform conformance testing for these properties.

40 MIL CHARACTERISTICS

PROPERTY	MINIMUM AVERAGE ROLL VALUES (unless otherwise indicated)			
	English		Metric	
	Units	Value	Units	Value
MODULUS OF ELASTICITY, ASTM D 882	psi	80,000	MPa	552
HYDROSTATIC RESISTANCE, ASTM D 751 A	psi	300	MPa	2.07
COEF. LINEAR THERMAL EXPANSION, Nominal	/°F	6.7×10^{-5}	/°C	1.2×10^{-4}
SOIL BURIAL RESISTANCE, NSF 54, Max. Change	percent	10	percent	10
OIT, 200°C, 1 atm O_2, Al pan	minutes	100	sec	6,000
TENSILE IMPACT, ASTM D 1822	ft·lbs/in^2	238	kJ/m^2	500
VOLATILE LOSS, ASTM D 1203A, Max.	percent	0.1	percent	0.1
OZONE RESISTANCE, ASTM D 1149, 168 hrs,100 pphm		No Cracks		No Cracks
WATER VAPOR TRANSMISSION, ASTM E 96, Max.			g/hr·m^2	0.008

STANDARD ROLL DIMENSIONS*	TYPICAL ROLL VALUES			
	English		Metric	
	Units	Value	Units	Value
WEIGHT	lbs	5,000	kg	2,270
WIDTH	ft	15.0	m	4.57
LENGTH	ft	1,670	m	509
AREA	ft^2	25,050	m^2	2,327

*VALUES ARE APPROXIMATE
CUSTOM ROLL SIZES AND HALF SIZE ROLLS ARE AVAILABLE
SHEET IS ROLLED ON 12" DIAMETER CORES

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NSC NATIONAL SEAL COMPANY

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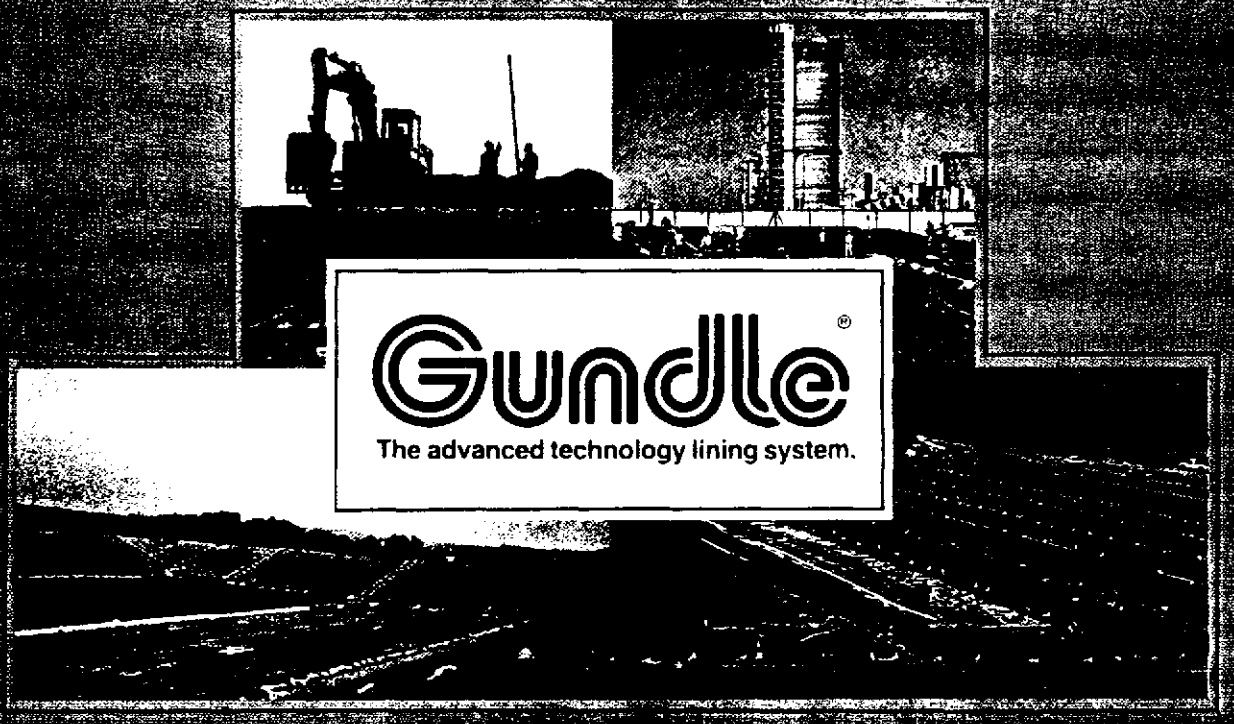
Only one company can be recognized as the leader in lining systems



With an unmatched selection of liner material, over 270 million square feet of installed liner, and turn-key installation service, Gundle stands alone as a supplier of lining systems.

A Liner For Every Application

Gundle manufactures three different materials for liner use. Each of these materials, Gundline HD, Hyperlastic, and Driline, offers a specific combination of price and performance. Gundline HD, a National Sanitation Foundation listed material, offers the long term durability necessary for use in the most demanding exposed or buried liner applications. Gundle's Hyperlastic is a high performance polyolefin copolymer with exceptional elastic properties that make it ideal for the toughest buried applications. Driline is a tough polyolefin copolymer that is priced competitively with PVC, yet delivers superior wear performance in buried applications. All Gundle materials are available in 22½' widths with no factory seams for ease of installation and maximum liner integrity. In addition to liner materials, Gundle also offers Gundnet drainage media and Gundfab geotextile for various leachate applications.

Gundle also provides design, construction, and installation services for liners, floating covers, and secondary containment systems through Gundle Lining Construction Corp.

There are 10 solid reasons why Gundle is recognized as the leading supplier of lining systems:

- Single source responsibility for all materials as well as design and installation
- Most extensive warranty in the industry
- Over 270 million square feet experience
- Liner materials manufactured in 22½' seamless widths
- Wide range of thicknesses, from 20 to 100 mil
- Patented extrusion welding system
- Meets all RCRA requirements for double liner systems
- Listed by the NSF for HDPE liners
- Full testing labs (including 90/90 testing)
- Over 22 years of international experience

Gundle Lining Systems Inc

Gundle®
A CLIFCOR Company

Gundle Road
1340 E. Richey Road
Houston, Texas 77073
U.S.A.

Phone: (713) 443-8564
Toll Free: (800) 435-2008
Telex: 4620281 Gundle Hou
Fax: (713) 875-6010

Gundle Lining Systems Inc

Gundle®

Gundline® HD

GUNDLINE® HD is a high quality formulation of High Density Polyethylene containing approximately 97.5% polymer and 2.5% of carbon black, anti-oxidants and heat stabilizers. The product was designed specifically for exposed conditions. It contains no additives or fillers which can leach out and cause embrittlement over time.

GUNDLINE® HD SPECIFICATIONS

PROPERTY	TEST METHOD	GAUGE (NOMINAL)								
		20 mil (0.5 mm)	30 mil (0.75 mm)	40 mil (1.0 mm)	50 mil (1.25 mm)	60 mil (1.5 mm)	80 mil (2.0 mm)	100 mil (2.5 mm)	120 mil (3.0 mm)	140 mil (3.5 mm)
Density (g/cc) (Minimum)	ASTM D1505	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Melt Flow Index (g/10 min.) (Max.)	ASTM D1238 Condition E (190°C, 2.16 kg.)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Minimum Tensile Properties (Each direction)	ASTM D638 Type IV Dumb-bell at 2 ipm.									
1. Tensile Strength at Break (Pounds/inch width)		80	120	160	200	240	320	400	480	560
2. Tensile Strength at Yield (Pounds/inch width)		50	70	95	115	140	190	240	290	340
3. Elongation at Break (Percent)		700	700	700	700	700	700	700	700	700
4. Elongation at Yield (Percent)		13	13	13	13	13	13	13	13	13
5. Modulus of Elasticity (Pounds per square inch × 10^5)	ASTM D882	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Tear Resistance Initiation (Min. lbs.)	ASTM D1004 Die C	15	22	30	37	45	60	75	90	105
Low Temperature/Brittleness (°F)	ASTM D746 Procedure B	−112	−112	−112	−112	−112	−112	−112	−112	−112
Dimensional Stability (Each direction, % change max.)	ASTM D1204 212°F 1 hr.	±2	±2	±2	±2	±2	±2	±2	±2	±2
Volatile Loss (Max. %)	ASTM D1203 Method A	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Resistance to Soil Burial (Maximum percent change in original value)	ASTM D3083 using ASTM D638 Type IV Dumb-bell at 2 ipm.									
Tensile Strength at Break and Yield	% Change	±5	±5	±5	±5	±5	±5	±5	±5	±5
Elongation at Break and Yield	% Change	±10	±10	±10	±10	±10	±10	±10	±10	±10
Ozone Resistance	ASTM D1149 7 days 100 ppm, 104°F Magnification	No cracks 7×	No cracks 7×	No cracks 7×	No cracks 7×	No cracks 7×	No cracks 7×	No cracks 7×	No cracks 7×	No cracks 7×
Environmental Stress Crack (Minimum hours)	ASTM D1693* (10% Igepal, 50°C)	1500	1500	1500	1500	1500	1500	1500	1500	1500
Puncture Resistance (Pounds)	FTMS 101B Method 2065	26	40	52	65	80	110	140	160	180
Water Absorption (Max. % wt. change)	ASTM D570	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Hydrostatic Resistance (Pounds/square inch)	ASTM D751 Method A Procedure I	160	240	315	402	490	650	810	970	1130
Coefficient of Linear Thermal Expansion ($\times 10^{-4} \frac{cm}{cm\,°C}$) Nominal	ASTM D696	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Moisture Vapor Transmission ($g/m^2 \cdot day$)	ASTM E96	0.06	0.05	0.04	0.035	0.03	0.02	0.01	0.007	0.005
Thermal Stability Oxidative Induction Time (OIT) (minutes, minimum)	ASTM D3895 130°C, 800 psi O_2	2000	2000	2000	2000	2000	2000	2000	2000	2000

Note: Testing longer than 1500 hours is unnecessary because after 1500 hours polyethylene relaxes in the bent condition of the test.

PRODUCT DESCRIPTION

JOINING SYSTEMS

Critical to the success of any flexible membrane liner is the joining system. Gundle's patented Extrusion Welding System is used to join individual panels of GUNDLINE® HD. Request your copy of the Gundle Extrusion Welding bulletin for complete details.

CHEMICAL RESISTANCE

GUNDLINE HD is resistant to a wide range of chemicals including acids, alkalis, salts, alcohols, amines, oils, and other hydrocarbons. Since combinations of chemicals of different concentrations and temperatures have different characteristics, consult Gundle for specific application details. *Write for Gundle's chemical compatibility information.*

SUPPLY SPECIFICATIONS

The following describes standard roll dimensions for GUNDLINE HD.

THICKNESS		WIDTH		LENGTH		AREA		ROLL WEIGHT	
mil	mm	ft	m	ft	m	ft^2	m^2	lb	kg
20	0.5	22.5	6.86	1250	381	28,125	2613	2800	1272
30	0.75	22.5	6.86	840	256	18,900	1756	2800	1272
40	1.0	22.5	6.86	650	198	14,625	1359	2800	1272
50	1.25	22.5	6.86	500	152	11,250	1043	2800	1272
60	1.5	22.5	6.86	420	128	9,450	878	2800	1272
80	2.0	22.5	6.86	320	98	7,200	670	2800	1272
100	2.5	22.5	6.86	250	76	5,625	522	2800	1272
120	3.0	22.5	6.86	210	64	4,725	439	2800	1272
140	3.5	22.5	6.86	180	55	4,050	377	2800	1272

GUNDLINE HD is rolled on 6" I.D. hollow cores.
Each roll is provided with 2 slings to aid handling on site.
Dimensions and weights are approximate. Custom lengths available on request.

Gundle Lining Systems Inc

Gundle®

Gundle Lining Systems Inc
19103 Gundle Road
Houston, Texas 77073
U.S.A.

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Gundline® HD — High Density Polyethylene NSF Listed

Gundline-HD is a high quality formulation of High Density Polyethylene containing approximately 97.5% polymer and 2.5% of carbon black, anti-oxidents and heat stabilizers. The product was designed specifically for exposed conditions. It contains no additives or fillers which can erode the product over time

CHEMICAL RESISTANCE Gundline-HD is resistant to a wide range of chemicals including acids, alkalis, salts, alcohols, amines, oils, and hydrocarbons. Since combinations of chemicals of different concentrations and temperatures have different characteristics, consult Gundle for specific application details. Write for Gundle's chemical compatibility information.

JOINING SYSTEMS Critical to the success of any flexible membrane liner is the joining system. Gundle's patented Extrusion Welding System is used to join individual panels of Gundline-HD. Request your copy of the Gundle Extrusion Welding Bulletin for complete details.

SUPPLY SPECIFICATION The following describes standard roll dimensions for Gundline-HD.

THICKNESS		WIDTH		LENGTH		AREA		ROLL WEIGHT	
mil.	mm	ft.	m.	ft	m.	ft.²	m²	lb.	kg
20	0.5	22.5	6.75	1250	381	28,125	2613	2800	1272
30	0.75	22.5	6.75	840	256	18,900	1756	2800	1272
40	1.0	22.5	6.75	650	198	14,625	1359	2800	1272
60	1.5	22.5	6.75	420	128	9,450	878	2800	1272
80	2.0	22.5	6.75	320	100	7,145	664	2800	1272
100	2.5	22.5	6.75	250	76	5,582	519	2800	1272

Driline — Polyolefin Copolymer

Driline is a high quality polyolefin copolymer particularly suited for landfill lining, caps, and buried lining applications.

Since Gundle Driline contains no plasticizers or volatile additives that may migrate out over time, it offers extended life in buried applications.

CHEMICAL RESISTANCE Driline is resistant to a wide range of chemicals including acids, alkalis, salts, alcohols, amines, oils, and hydrocarbons. Since combinations of chemicals of different concentrations and temperatures have different characteristics, consult Gundle for specific application details. Write for Gundle's chemical compatibility information.

JOINING SYSTEM Critical to the success of any flexible membrane liner is the joining system. Gundle's patented Extrusion Welding System is used to join individual panels of Driline. In addition to Extrusion Welding, Hot Wedge and other methods may be used.

SUPPLY SPECIFICATION The following describes standard roll dimensions for Driline.

THICKNESS		WIDTH		LENGTH		AREA		ROLL WEIGHT	
mil.	mm.	ft.	m.	ft.	m.	ft.²	m²	lb.	kg.
20	0.5	22.5	6.75	1250	381	28,125	2613	2800	1272
30	0.75	22.5	6.75	840	256	18,900	1756	2800	1272

Hyperlastic — High Performance Polyolefin Copolymer

Hyperlastic is a high performance polyolefin copolymer with exceptional elastic properties, making it ideal for buried lining applications.

Since Gundle Hyperlastic contains no plasticizers or volatile additives that may migrate out over time, it offers extended life in buried applications.

CHEMICAL RESISTANCE Hyperlastic is resistant to a wide range of chemicals including acids, alkalis, salts, alcohols, amines, oils, and hydrocarbons. Since combinations of chemicals of different concentrations and temperatures have different characteristics, consult Gundle for specific application details. Write for Gundle's chemical compatibility information.

JOINING SYSTEM Critical to the success of any flexible membrane liner is the joining system. Gundle's patented Extrusion Welding System is used to join individual panels of Hyperlastic. In addition to Extrusion Welding, other methods of joining used are: Adhesive, HF Electronic Welding and Mechanical joints.

SUPPLY SPECIFICATION The following describes standard roll dimensions for Hyperlastic.

THICKNESS		WIDTH		LENGTH		AREA		ROLL WEIGHT	
mil.	mm	ft.	m.	ft.	m.	ft.²	m²	lb.	kg
20	0.5	26	7.93	600	183	15,600	1451	1500	607
30	0.75	24	7.32	425	130	10,200	952	1500	607
40	1.0	23	7.01	350	107	8,050	750	1500	607

Gundnet — High Density Polyethylene Netting

Gundnet drainage netting can be used wherever drainage of fluids is required. Gundnet is constructed of two sets of HDPE strands which are superposed in such a way that a fluid can be easily conveyed along the plane of the net.

Gundnet drainage netting is a high density polyethylene product which offers all the advantages of HDPE in waste containment, including: superior resistance to a wide variety of chemicals; excellent durability over time and high tensile strength.

CHEMICAL RESISTANCE Gundnet offers the same resistance to chemicals as Gundline-HD. Please refer to above.

TRANSMISSIVITY The property which is generally of most interest when comparing different drainage layers is the flow rate of fluids through the drainage medium. This is referred to as hydraulic transmissivity.

One layer of Gundnet exceeds the hydraulic transmissivity of a 0.3m (12 inches) conventional sand and/or gravel drainage layer.

INSTALLATION Gundnet is unrolled and placed by hand to form a blanket for drainage where required. Gundnet rolls are of sizes and weights which do not require heavy equipment for installation, thereby reducing the risk of puncturing the underlying geomembrane.

Gundnet sections may be joined together by tying adjacent or overlying rolls together with conventional cable ties as used in the electronics industry.

SUPPLY SPECIFICATION The following describes standard roll dimensions for Gundnet.

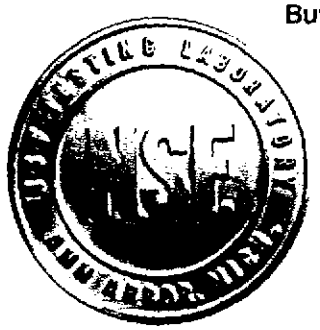
Gundnet	THICKNESS		WIDTH		LENGTH		AREA		ROLL WEIGHT	
	mil.	mm	ft.	m.	ft	m	ft.²	m²	lb.	kg.
G1	210	5.0	4.79	1.46	65.6	20	314.2	29.2	50.7	23.0
G2	210	5.0	6.56	2.00	82.0	25	537.9	50.0	82.7	37.5
G3	168	4.0	5.35	1.63	82.0	25	438.7	40.8	61.7	28.0

CHEMICAL RESISTANCE

In order to provide a guide for engineers seeking suitable plastic membranes for lining applications, this resistance guide has been tabulated from information both obtained from our own laboratories, as well as from a variety of other sources.

Our range of plastics are primarily inert, particularly stable, and contain no plasticizers. They exhibit a resistance to a wide range of chemicals. Chemical resistance refers to the liners' ability to withstand two main kinds of attack by chemicals. The one is their resistance to chemical attack and the other relates to their resistance to absorption and swelling and consequent weakening.

It is important to note that mixtures of chemicals do not necessarily have the same effect or lack of effect on a plastic than do each of the individual components. Chemical attack can be influenced by temperature, contact time, concentration and composition. **It is recommended that immersion tests be carried out at the design stage of the project in order to confirm the suitability of the type of membrane selected.**



GUNDLINE ® HD

CHEMICAL RESISTANCE RATING GUIDE – DATA BASED ON IMMERSION AT 25°C (77°F)

O — No effect
M — Moderate effect
S — Severe effect

	HD	DRI	HYP
WATER			
Distilled Water	O	O	O
Sea Water — Atlantic	O	O	O
Sea Water — Pacific	O	O	O
INORGANIC ACIDS			
Boric Acid (10%)	O	O	O
Chlorosulphonic Acid (10%)	S	S	S
Chromic Acid (10%)	O	S	S
Chromic Acids (Conc.)	M	S	S
Hydrochloric Acid (10%)	O	O	O
Hydrochloric Acid (Conc.)	O	M	M
Hydrofluoric Acid (Conc.)	O	M	M
Nitric Acid (10%)	O	O	O
Phosphoric Acid (Conc.)	O	O	M
Sulphuric Acid (10%)	O	O	O
Sulphuric Acid (Conc.)	M	M	M
INORGANIC BASES			
Ammonium Hydroxide (10%)	O	O	O
Ammonium Hydroxide (Conc.)	O	O	O
Barium Hydroxide (Conc.)	O	O	O
Calcium Hydroxide (10%)	O	O	O
Potassium Hydroxide (10%)	O	O	O
Sodium Hydroxide (10%)	O	O	O
Sodium Hydroxide (Conc.)	O	O	O
INORGANIC SALTS (25% Solution)			
Aluminum Chloride	O	O	O
Aluminum Sulphate	O	O	O
Ammonium Chloride	O	O	O
Ammonium Nitrate	O	O	O
Ammonium Phosphate	O	O	O
Barium Chloride	O	O	O
Barium Sulphide	O	O	O
Calcium Chloride	O	O	O
Calcium Hypochlorite	O	O	O
Cupric Chloride	O	O	O
Cupric Sulphate	O	O	O
Ferric Chloride	O	O	M
Ferric Nitrate	O	O	M
Ferrous Sulphate	O	O	O
Magnesium Chloride	O	O	O
Magnesium Sulphate	O	O	O
Nickel Sulphate	O	O	O
Potassium Chloride	O	O	O
Potassium Permangenate	O	O	S
Potassium Bisulphite	O	O	O
Potassium Dichromate	O	O	O
Sodium Borate (Borax)	O	O	O
Sodium Bicarbonate	O	O	O
Sodium Chloride	O	O	O
Zinc Chloride	O	O	O
Zinc Nitrate	O	O	O
Sodium Chloride – Saturated	O	O	O
ORGANIC ACIDS			
Acetic Acid (10%)	O	O	O
Acetic Acid (Glacial)	O	M	O
Chloracetic Acid (10%)	O	O	O
Citric Acid (10%)	O	O	O
Formic Acid (10%)	O	O	O
Lactic Acid (10%)	O	O	O
Oleic Acid (100%)	O	S	S
Oxalic Acid (10%)	O	O	O
Phenol (10%)	O	M	M
Phenol (100%)	O	S	S
Picric Acid (10%)	O	O	O
Stearic Acid (100%)	O	O	O
Tannic Acid (10%)	O	O	O
Tartaric Acid (10%)	O	O	O
ALCOHOLS			
Benzyl Alcohol	O	S	S
Ethyl Alcohol	O	M	O
Isopropyl Alcohol	O	M	O
Methyl Alcohol	O	M	O
Ethylene Glycol	O	O	O
Methyl Ethyl Ketone	O	M	S
Methyl Isobutyl Ketone	O	S	S
Glycerol	O	O	O
1-Hexanol	O	O	O
Resorcinol	O	O	O
ALDEHYDES			
Benzaldehyde	O	S	S
Butraldehyde	O	S	S
Furfural	O	S	S
AMINES			
Aniline	O	S	S
Triethanolamine	O	M	S
ESTERS			
Amyl Acetate	O	S	S
Dibutyl Sebacate	O	M	S
Dioctyl Phthalate	O	M	S
Ethyl Acetate	O	M	S
Tricresyl Phosphate	O	M	S
ETHERS			
Dibenzyl Ether	M	S	S
Diethylene Glycol Monobutyl Ether	M	S	S
Ethyl Ether	M	S	S
Ethylene Glycol Monoethyl Ether	M	S	S
HYDROCARBONS			
Benzene	M	S	S
Cyclohexane	O	S	S
Ethylbenzene	M	S	S
Heptane	M	S	S
Hexane	M	S	S
Napthalene	O	S	S
Toluene	M	S	S
Xylene	M	S	S
HALOGENATED HYDROCARBONS			
Benzyl Chloride	S	S	S
Bromobenzene	S	S	S
Carbon Tetrachloride	M	S	S
Chloroform	S	S	S
Ethylene Dichloride	S	S	S
Perchloroethylene	S	S	S
OTHER SUBSTITUTED HYDROCARBONS			
Carbon Disulphide	M	S	S
Nitrobenzene	O	S	S
KETONES			
Acetone	O	S	S
DETERGENTS & OTHER CLEANING PRODUCTS			
Calgonite (1%)	O	O	O
Chlorox (1%)	O	O	O
Chlorox (Conc.)	O	O	O
Joy (1%)	O	O	O
Joy (Conc.)	O	O	O
Lestoil (1%)	O	O	O
Lux Flakes (1%)	O	O	O
Rinse Dry (1%)	O	O	O
Rinse Dry (Conc.)	O	O	O
Tide (1%)	O	O	O
NATURAL FATS & OILS			
Butter	O	O	S
Castor Oil	O	O	S
Cottonseed Oil	O	O	S
Lard	O	O	S
Oleomargarine	O	O	S
Olive Oil	O	O	S
White Mineral Oil	O	O	S
OILS & FUELS			
A.S.T.M. No. 1 Oil	O	S	S
A.S.T.M. No. 2 Oil	O	S	S
A.S.T.M. No. 3 Oil	O	S	S
A.S.T.M. Fuel A	O	S	S
A.S.T.M. Fuel B	O	S	S
A.S.T.M. Fuel C	O	S	S
Heating Fuel Oil	O	S	S
Jet Aircraft Engine Oil	O	S	S
HYDRAULIC FLUIDS			
Oronite 8200	M	S	S
Pydraul F 9	M	S	S
Pydraul 60	M	S	S
Skydrol	M	S	S
Skydrol 500	M	S	S
MISCELLANEOUS			
Gelatine (sat. sol'n)	O	O	O
Glucose (sat. sol'n)	O	O	O
Tincture of Iodine	O	S	M
Prestone antifreeze	O	O	O
Dowgard antifreeze	O	O	O

The information and recommendations contained in this bulletin are based on data which we believe are reliable but all such information and recommendations are given without guarantee or warranty.

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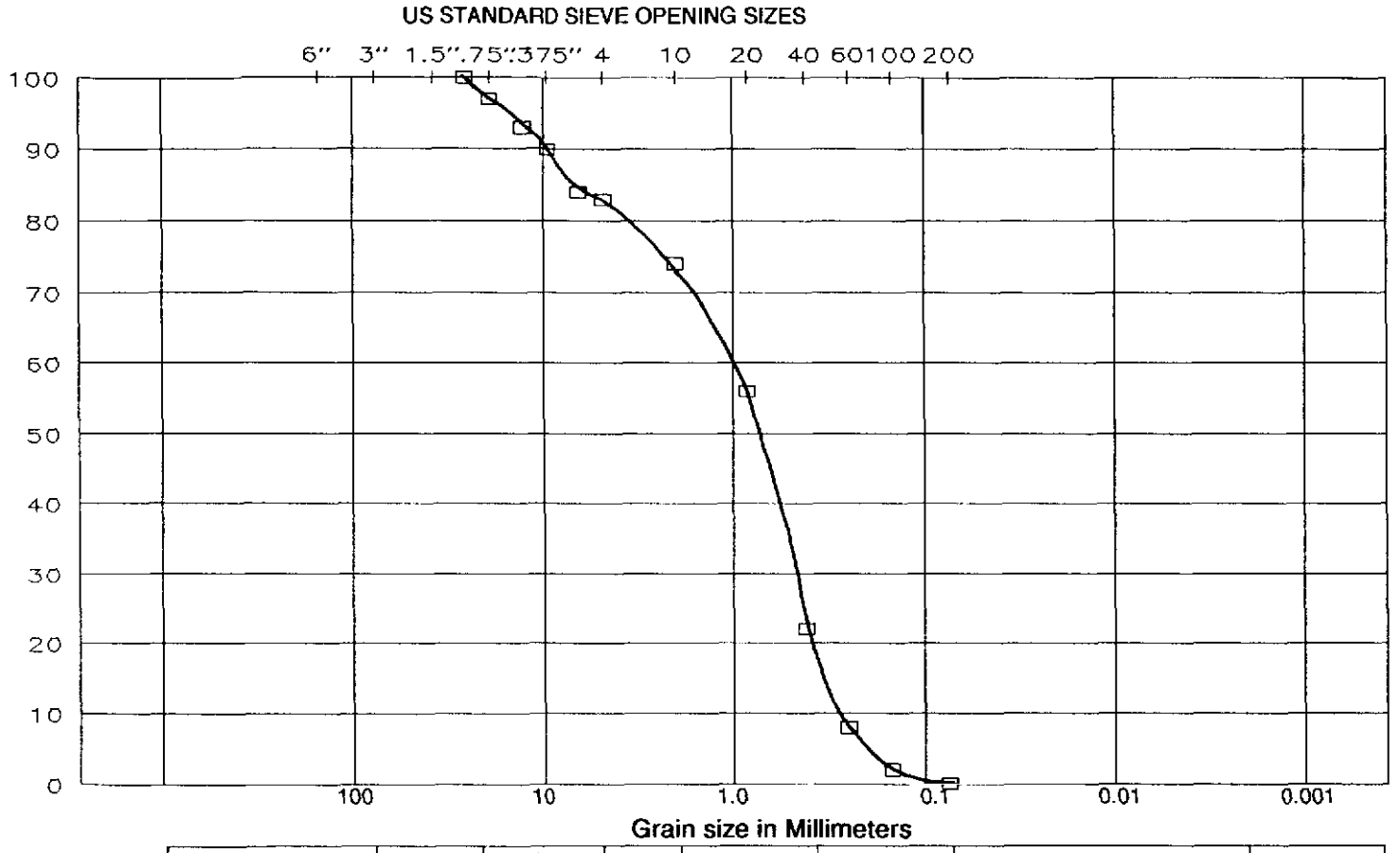
APPENDIX B

Soil Borrow Laboratory Data

Grain Size Distribution

PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



COBBLES	GRAVEL: coarse	GRAVEL: fine	SAND: c	SAND: med	SAND: fine	SILT	CLAY

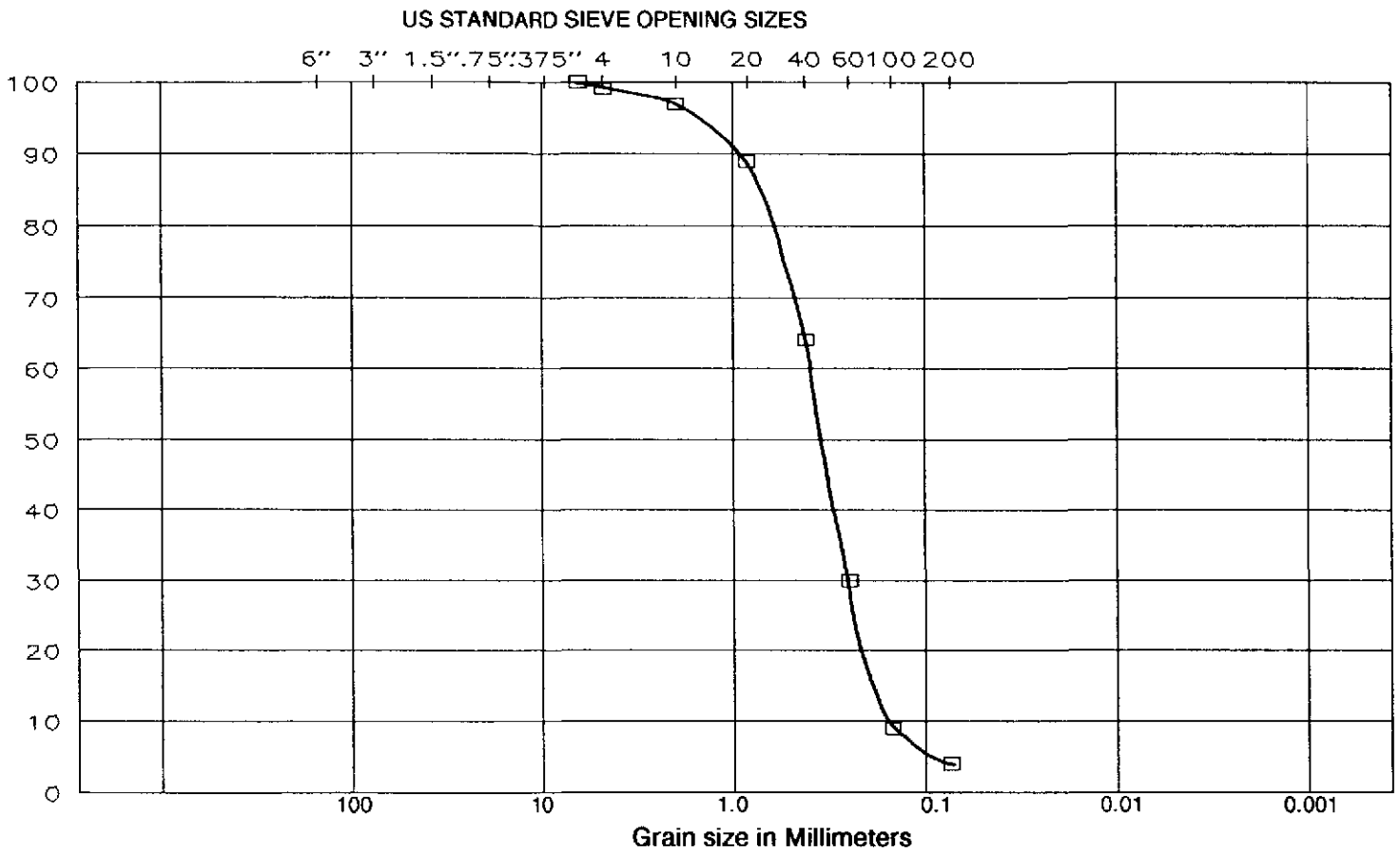
SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Townsend Sand	4.0	NP	NP	NP	Gs=2.74	Moderate yellowish brown m-f SAND,some f gravel, trace silt (SP)
Sample Type:	Bulk	Date Tested:		5/24/90	USDA:	Very Gravelly Sand

ISRT/WOBURN/MA

893-6255.10

GOLDER ASSOCIATES INC.
Consulting Engineers

PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



COBBLES	coarse	fine	c	med	fine	SILT	CLAY
	GRAVEL		SAND				

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Ashburnham Sand	2.9	NP	NP	NP	Gs=2.70	Moderate yellowish brown m-f SAND,trace silt (SP)
Sample Type:	Bulk	Date Tested:		5/24/90	USDA:	Sand

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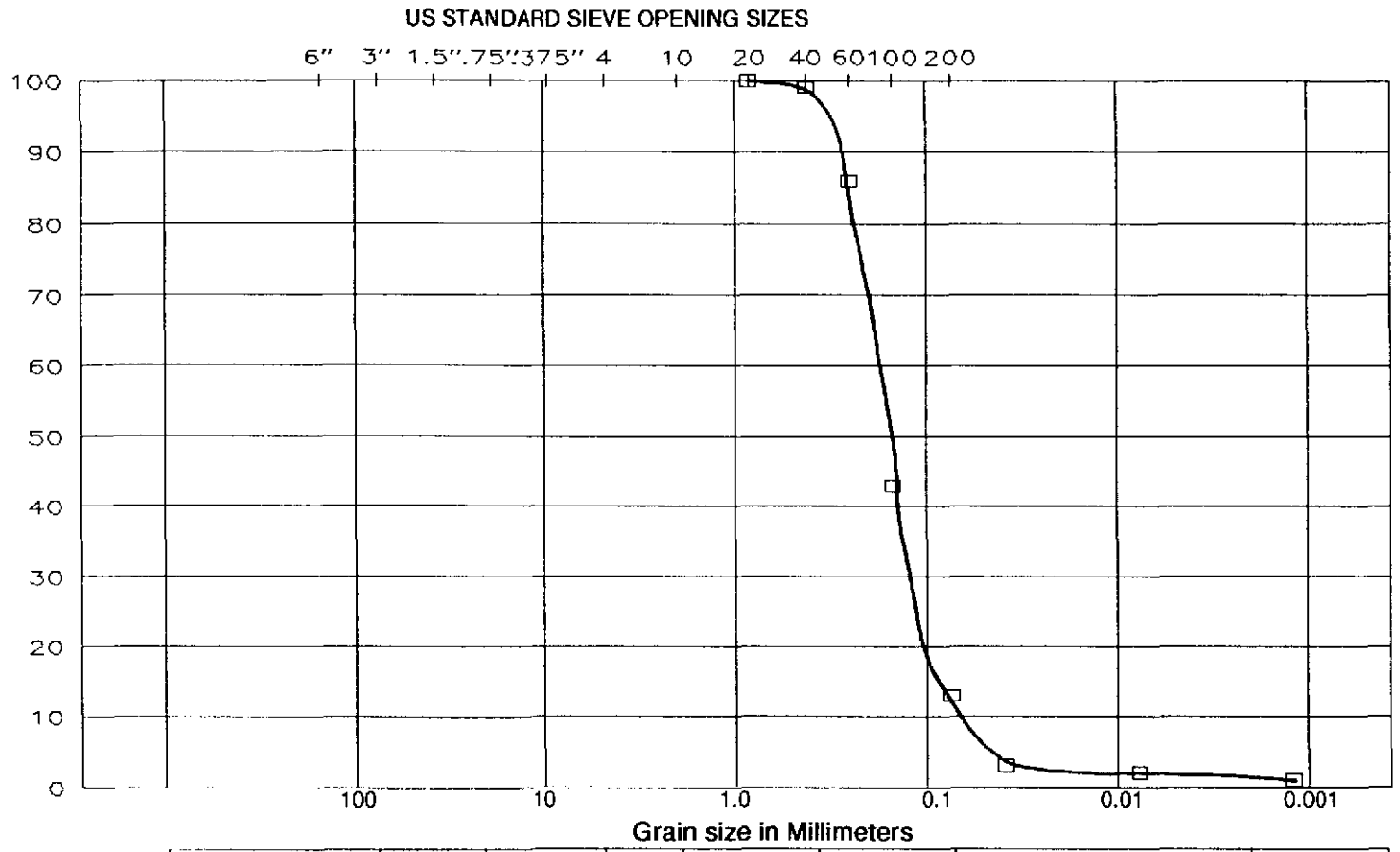

COBBLES	coarse	fine	c	med	fine	SILT	CLAY
	GRAVEL		SAND				

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Winchendon Sand	7.0	NP	NP	NP	Gs=2.75	Grayish orange f SAND,some silt (SM)
Sample Type:	Bulk	Date Tested:		5/24/90	USDA:	Sand

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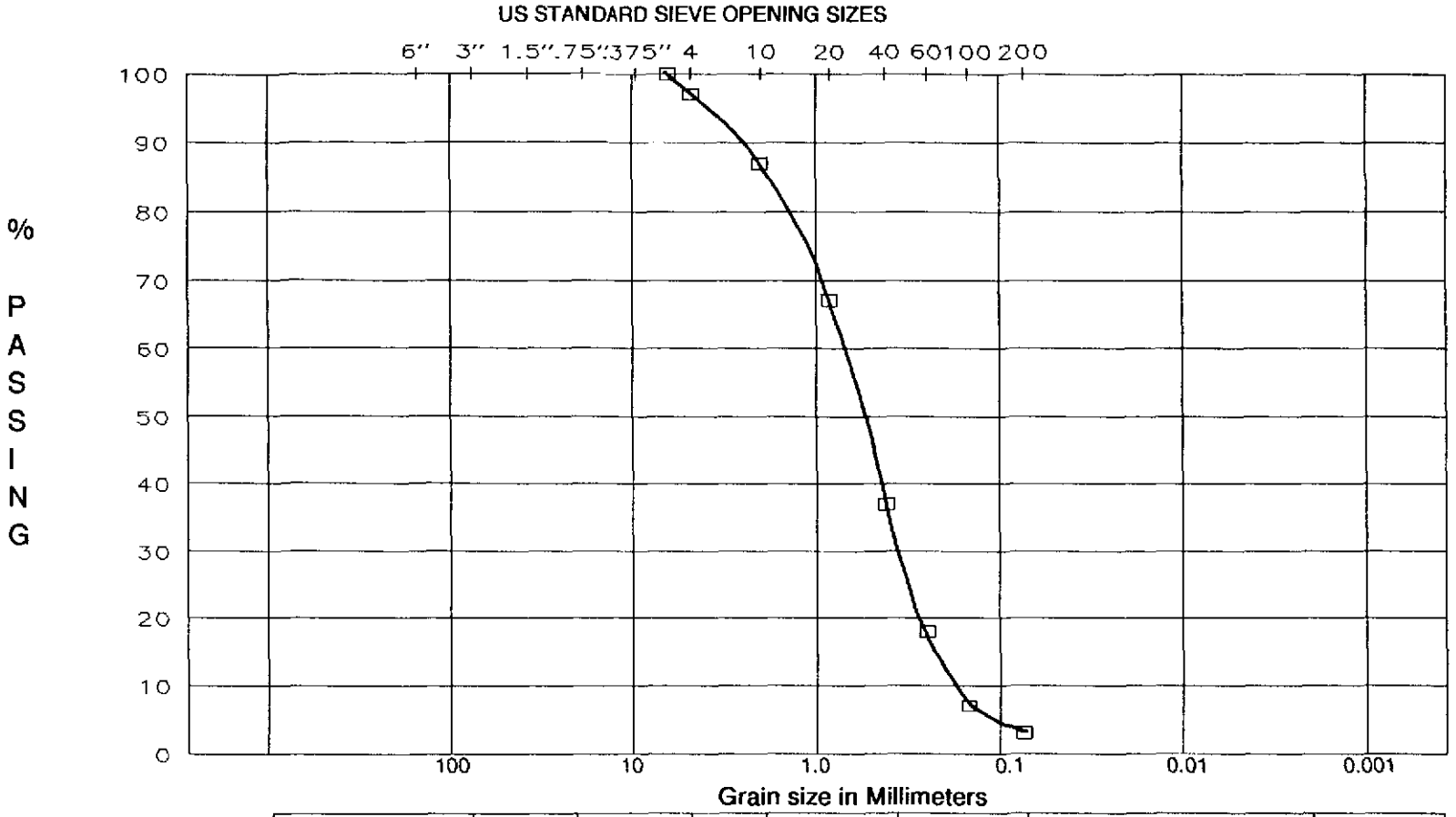
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



	coarse	fine	c	med	fine		
COBBLES	GRAVEL		SAND			SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Hubbardston Sand	3.2	NP	NP	NP	Gs=2.75	Dark yellowish orange c-f SAND, trace f gravel, trace silt (SP)
Sample Type:	Bulk	Date Tested:		5/24/90	USDA:	Gravelly Sand

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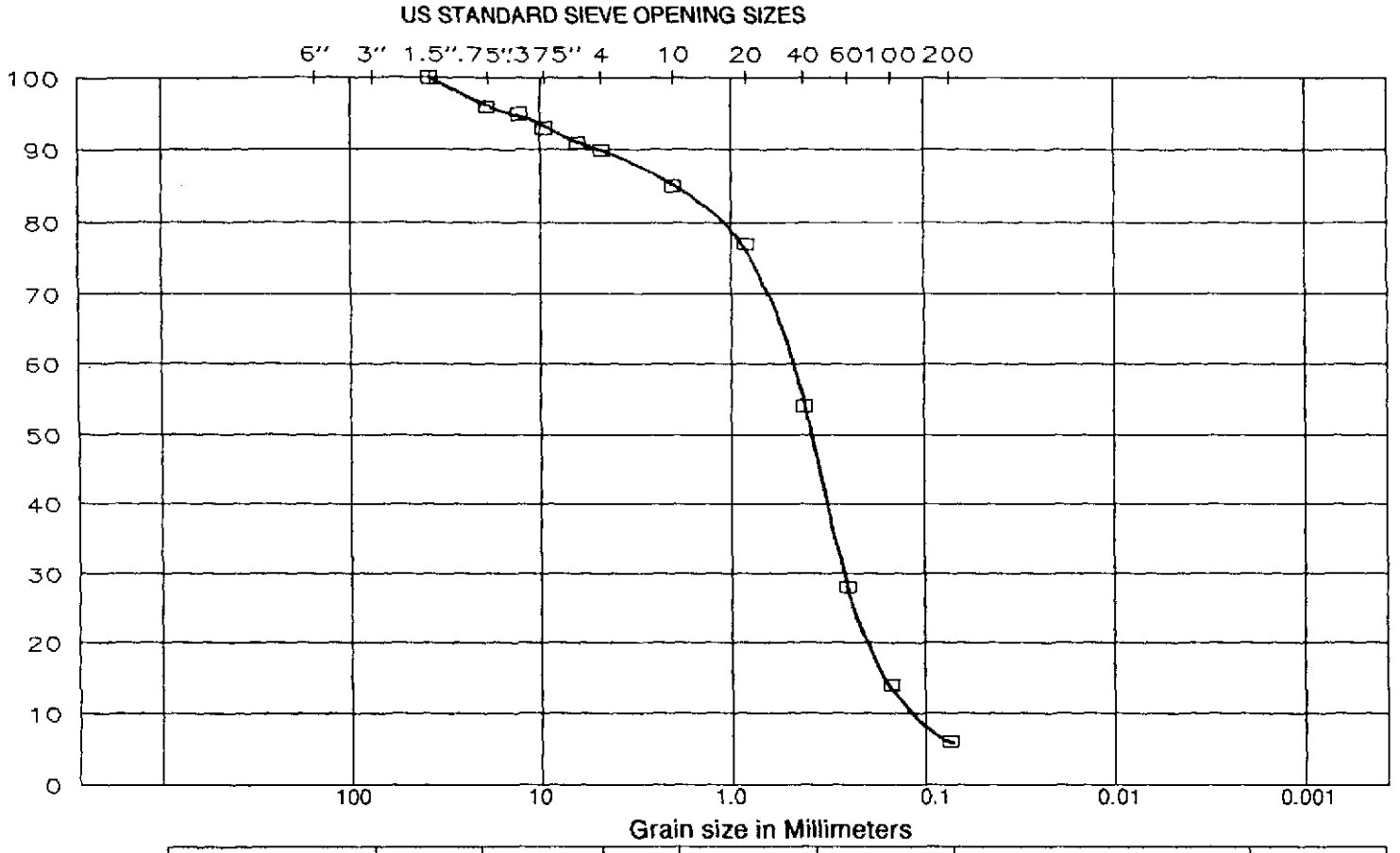

	coarse	fine	c	med	fine		
COBBLES	GRAVEL		SAND			SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Hubbardston Sand/Gravel	6.6	NP	NP	NP	Gs-2.82	Moderate yellowish brown m-f SAND,little c-f gravel little silt (SP-SM)
Sample Type:	Bulk	Date Tested:		5/24/90	USDA:	Very Gravelly Sand

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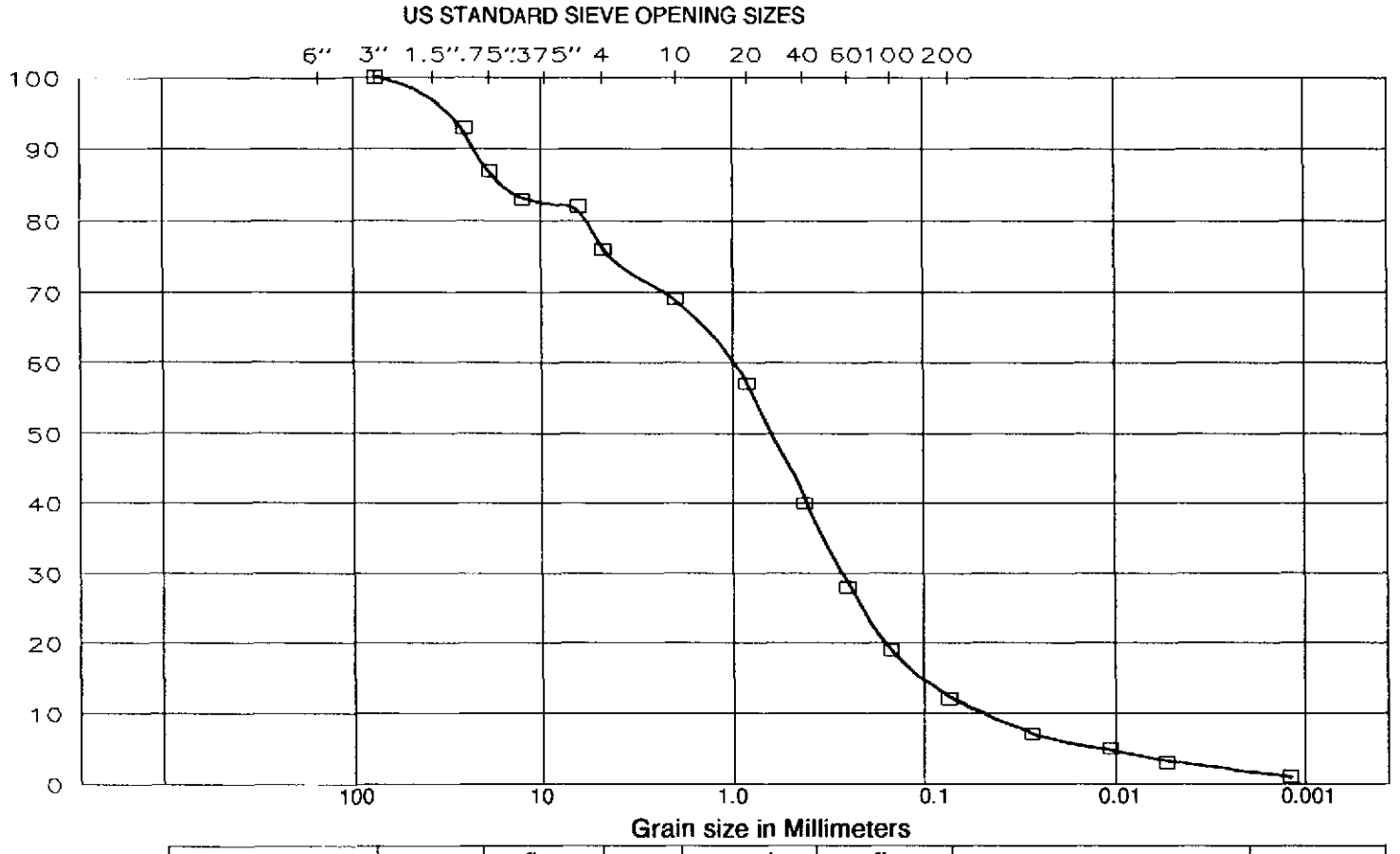

COBBLES	coarse	fine	c	med	fine	SILT	CLAY
	GRAVEL		SAND				

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
QUINN PERKINS PREPARED GRAVEL	5.6	NP	NP	NP	Gs.=2.81	Dark yellowish brown m-f SAND, some c-f gravel, little silt (SP-SM)
Sample Type:	BULK	Date Tested:		7/21/90	USDA:	Very Gravelly loamy sand

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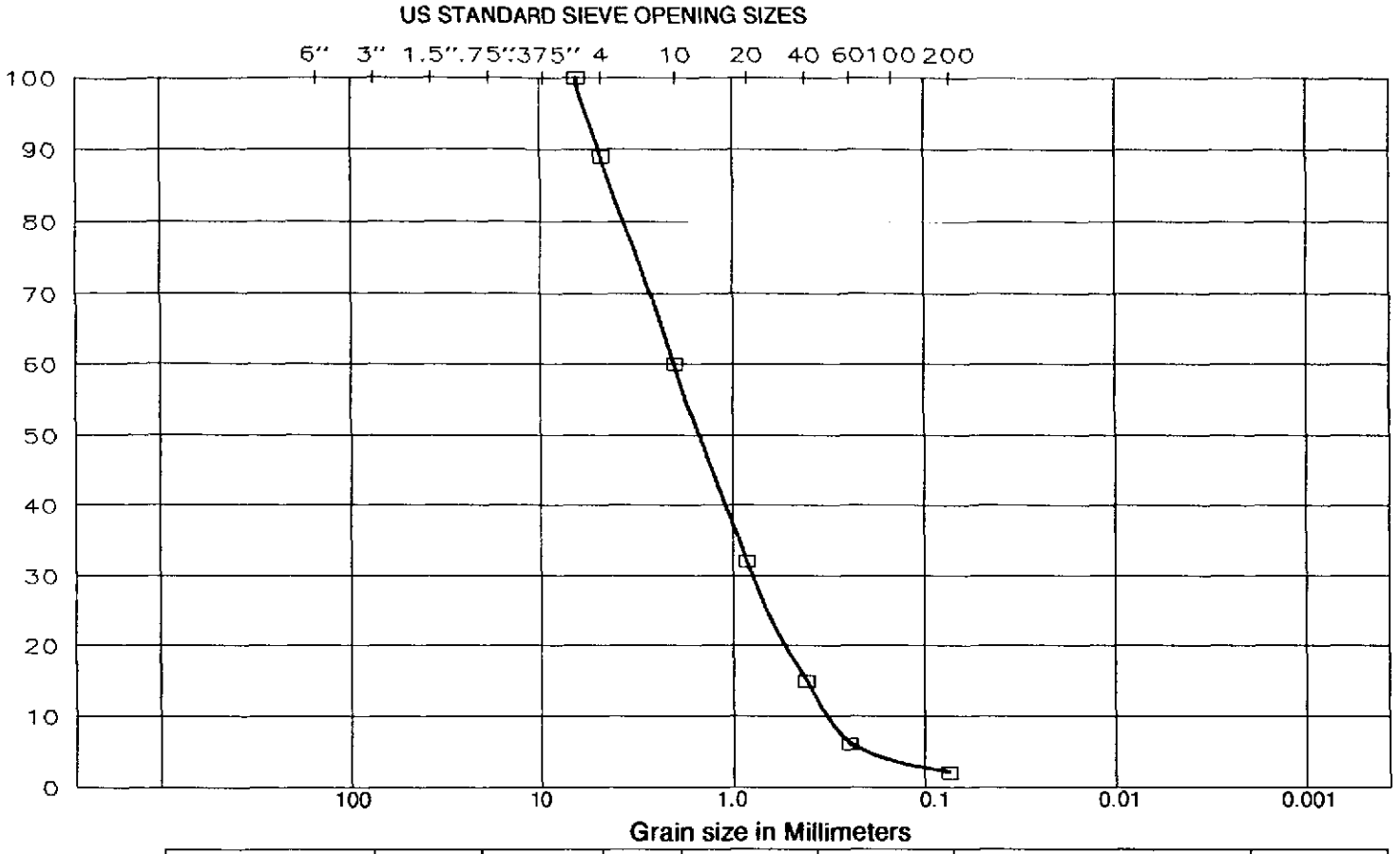
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



	coarse	fine	c	med	fine		
COBBLES	GRAVEL		SAND			SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Quinn Perkins Concrete Sand	2.2	NP	NP	NP	Gs=2.85	Dark yellowish orange c-f SAND,trace silt trace gravel (SW)
Sample Type:	Bulk	Date Tested:		7/21/90	USDA:	Very Gravelly Sand

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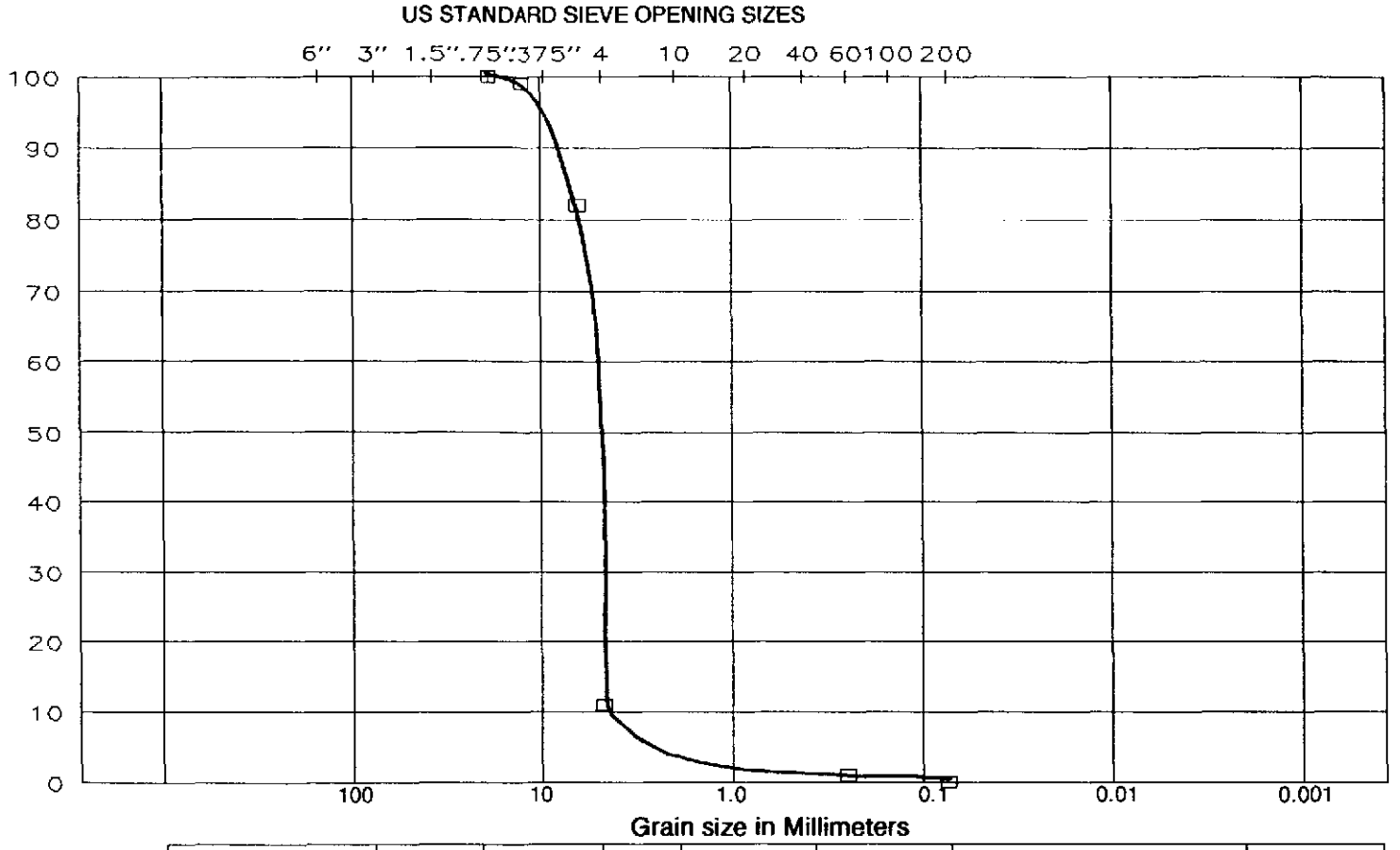
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



	coarse	fine	c	med	fine		
COBBLES	GRAVEL		SAND			SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Quinn Perkins 3/8 Stone	1.0					Grey,multicolored f GRAVEL,little c sand, trace silt (GP)
Sample Type:	Bulk	Date Tested:		7/21/90	USDA:	Extremely Gravelly Sand

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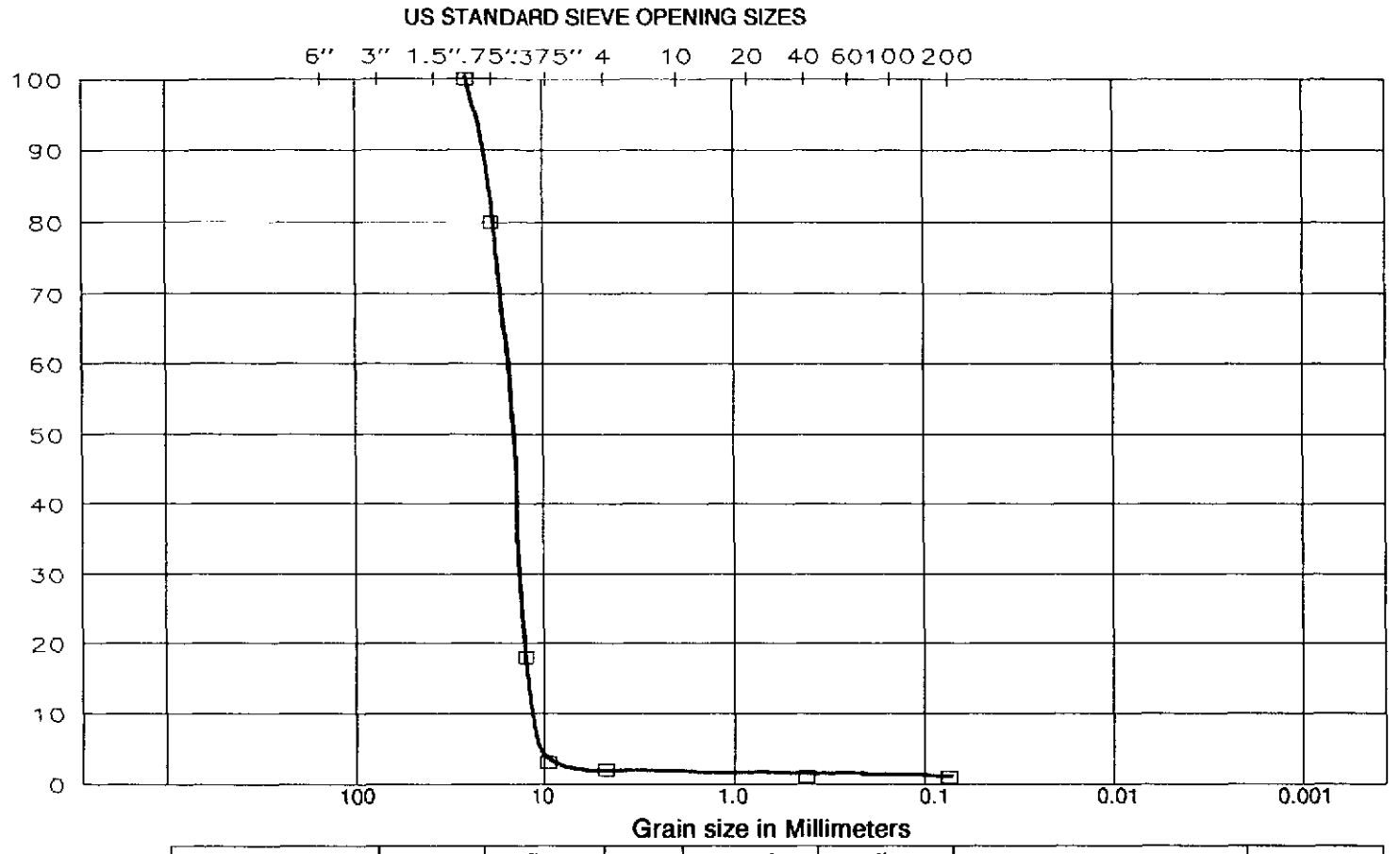
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



COBBLES	coarse GRAVEL	fine GRAVEL	c SAND	med SAND	fine SAND	SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Quinn Perkins 3/4" Stone	0.1					Multi-colored (grays,whites) c-f GRAVEL,trace sand, trace silt (GP)
Sample Type:	Bulk	Date Tested:		7/21/90	USDA:	Extremely Gravelly Sand

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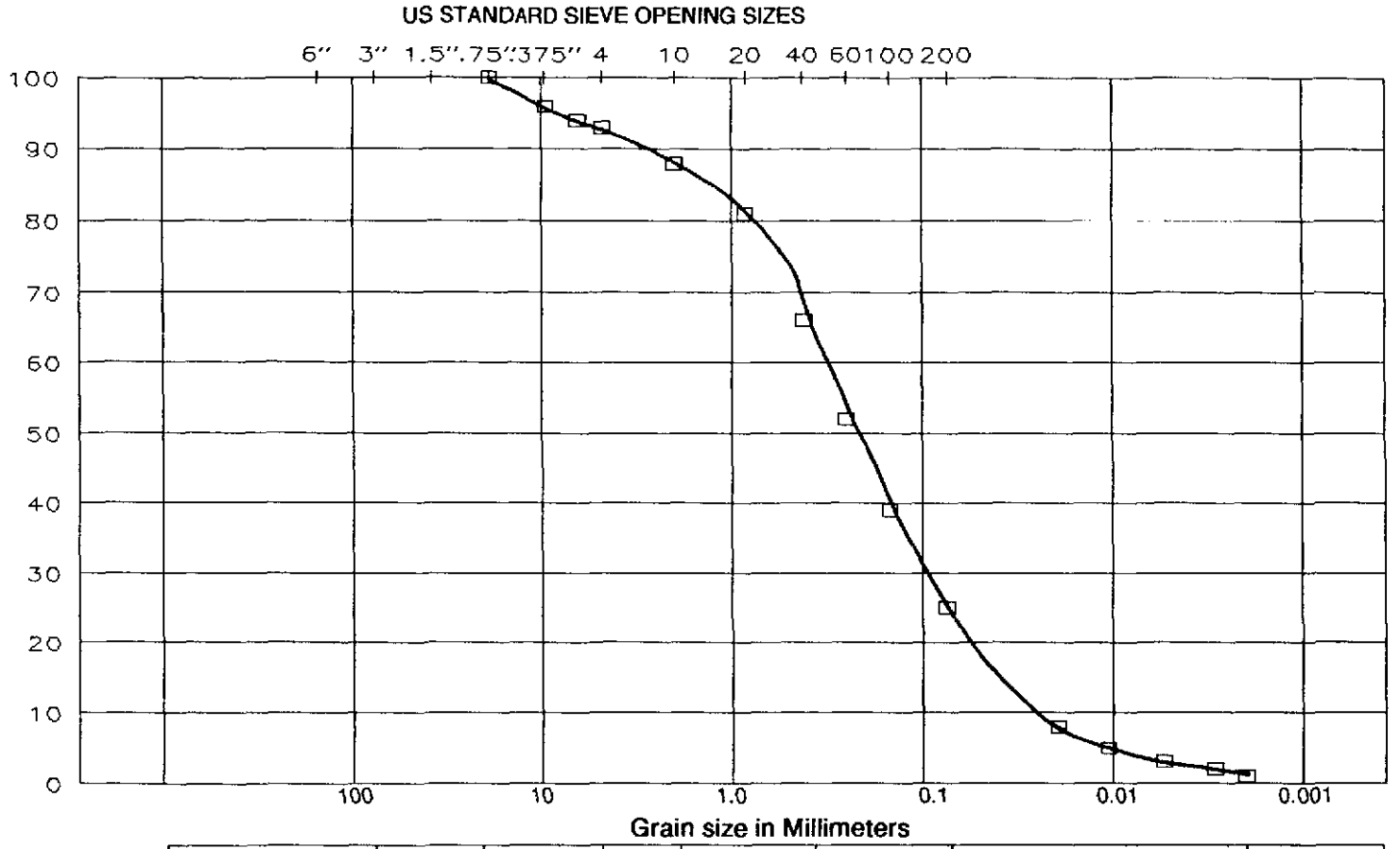
Consulting Engineers

PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



	coarse	fine	c	med	fine		
COBBLES	GRAVEL		SAND			SILT	CLAY

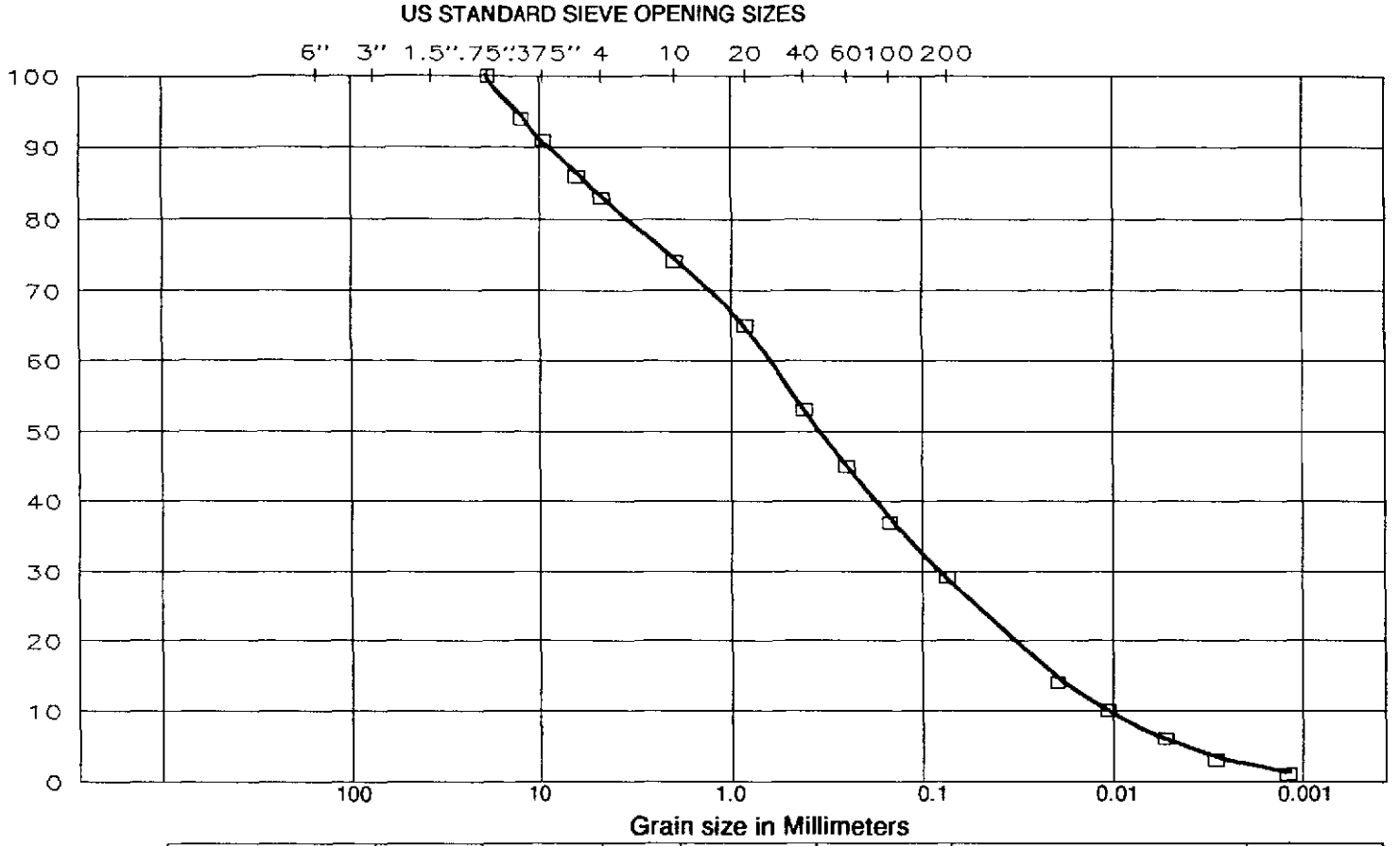
SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Billerica Topsoil	30.3	NP	NP	NP	Gs=2.63	Dusky yellowish brown m-f SAND,some silt, little f gravel (SM)
Sample Type:	BULK	Date Tested:		5/24/90	USDA:	Very Gravelly Sandy Loam

ISRT/WOBURN/MA

893-6255.10

GOLDER ASSOCIATES INC.
Consulting Engineers

PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



COBBLES	GRAVEL: coarse	GRAVEL: fine	SAND: c	SAND: med	SAND: fine	SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Hubbardston Topsoil	22.0	NP	NP	NP	Gs=2.66	Dusky yellowish brown c-f SAND,some silt, some f gravel (SM)
Sample Type:	BULK	Date Tested:	5/24/90		USDA:	Very Gravelly Sandy Loam

ISRT/WOBURN/MA

893-6255.10

GOLDER ASSOCIATES INC.
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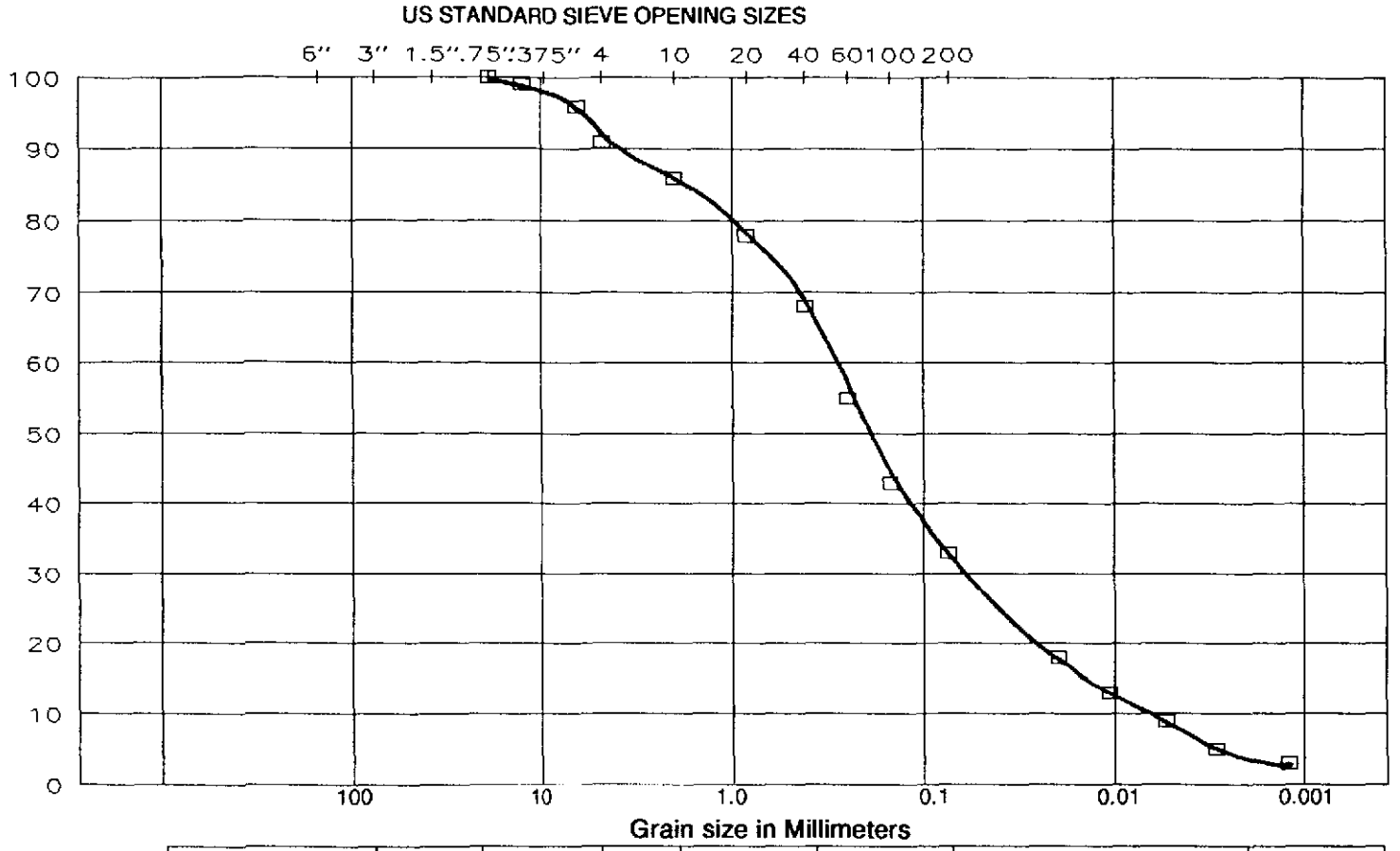
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



COBBLES	GRAVEL: coarse	GRAVEL: fine	SAND: c	SAND: med	SAND: fine	SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Kane Perkins Loam Topsoil Screened	16.8	NP	NP	NP		Medium to dark brown black m-f SAND and SILT, little gravel (SM)
Sample Type:	Bulk	Date Tested:		7/21/90	USDA:	Gravelly Sandy Loam

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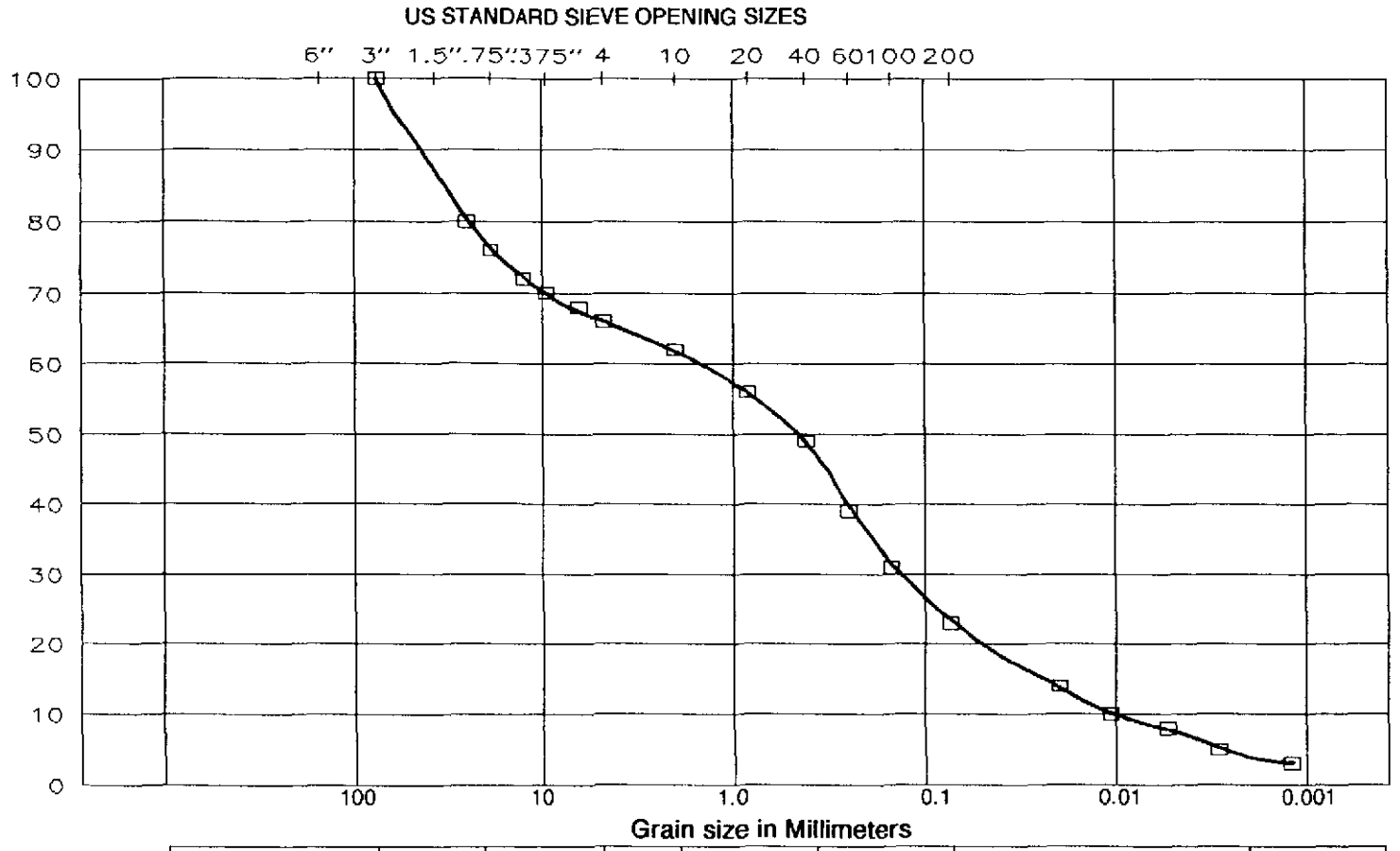
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



	coarse	fine	c	med	fine		
COBBLES	GRAVEL		SAND			SILT	CLAY

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
KP LOAM Unscreened #1	15.4	NP	NP	NP		Dark yellowish brown m-f SAND and c-f GRAVEL some silt (SM)
Sample Type:	BULK	Date Tested:		8/16/90	USDA:	Extremely Gravelly Sandy Loam

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893-6255.10

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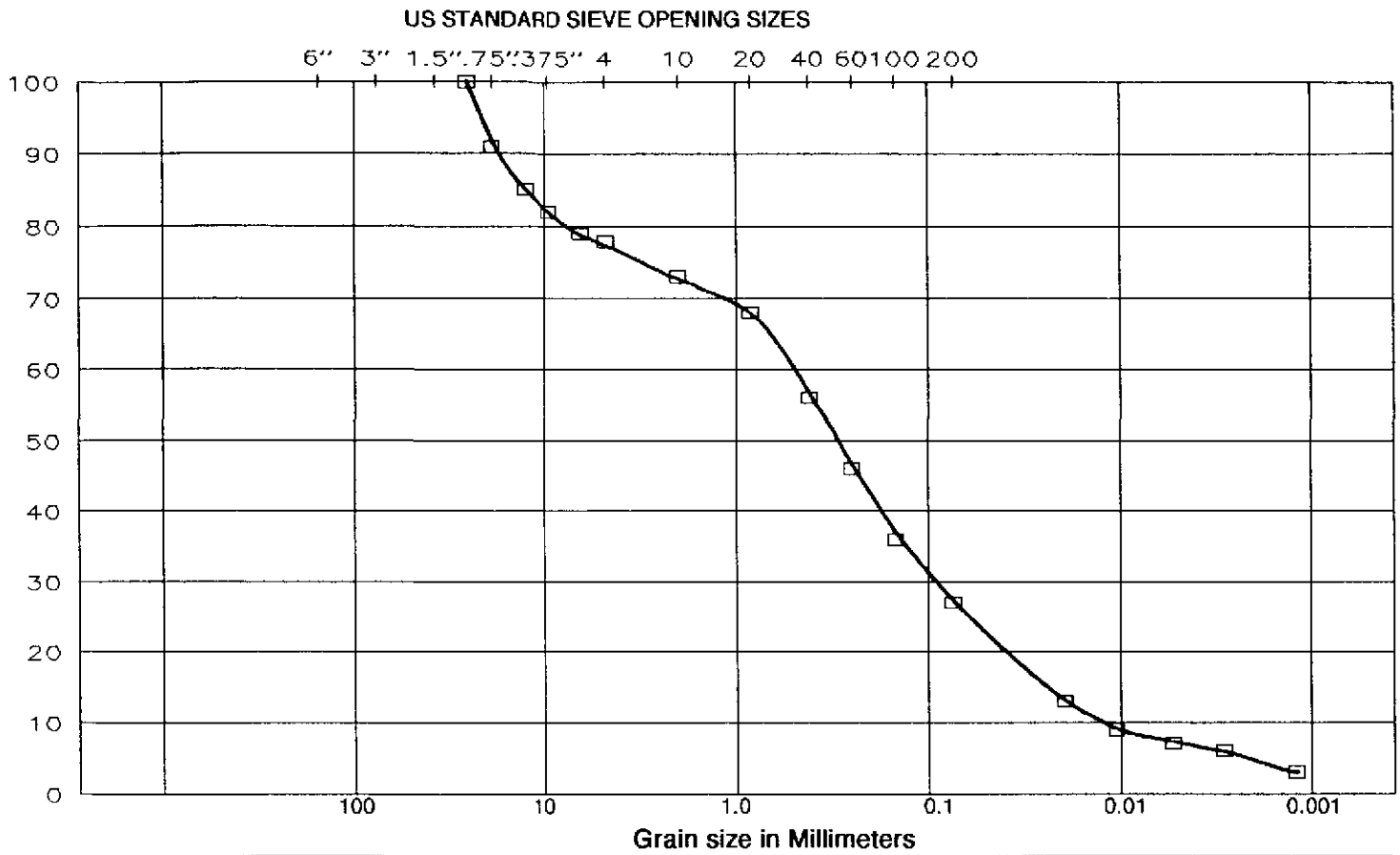
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



COBBLES	coarse	fine	c	med	fine	SILT	CLAY
	GRAVEL		SAND				

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
KP LOAM Unscreened #2	17.5	NP	NP	NP		Dark yellowish brown m-f SAND,some silt some gravel (SM)
Sample Type:	BULK	Date Tested:		8/01/90	USDA:	Extremely Gravelly Sandy Loam

ISRT/WOBURN/MA

893-6255.10

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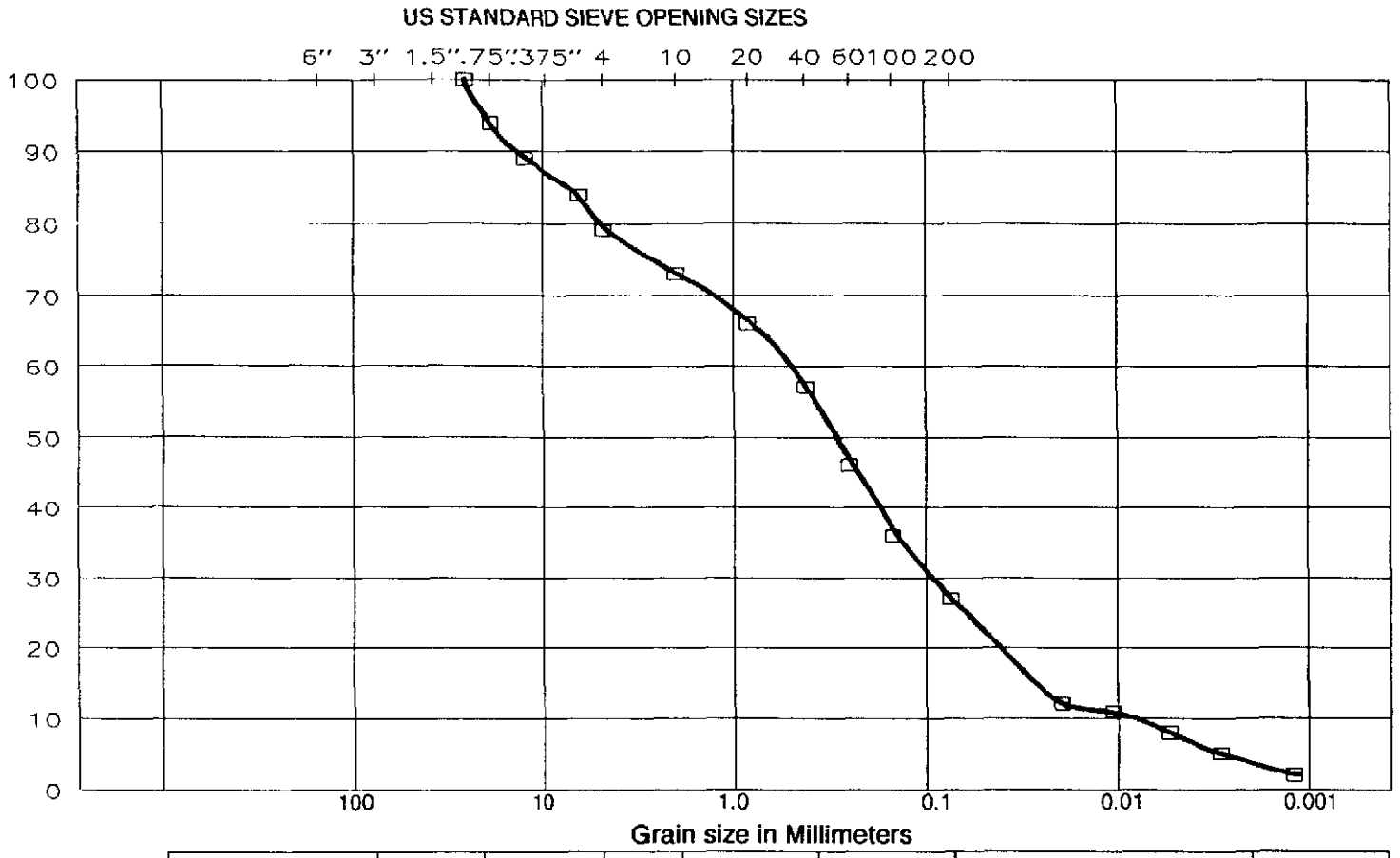
PARTICLE SIZE DISTRIBUTION ASTM D-421 AND 422



COBBLES	coarse	fine	c	med	fine	SILT	CLAY
	GRAVEL		SAND				

SAMPLE ID	W%	LL	PL	PI	Other	DESCRIPTION
Kane Perkins Loam Topsoil Unscreened	19.7	NP	NP	NP	Composit	Grayish Brown m-f SAND,some silt some gravel (SM)
Sample Type:	Bulk	Date Tested:		7/21/90	USDA:	Very Gravely Sandy Loam

ISRT/WOBURN/MA

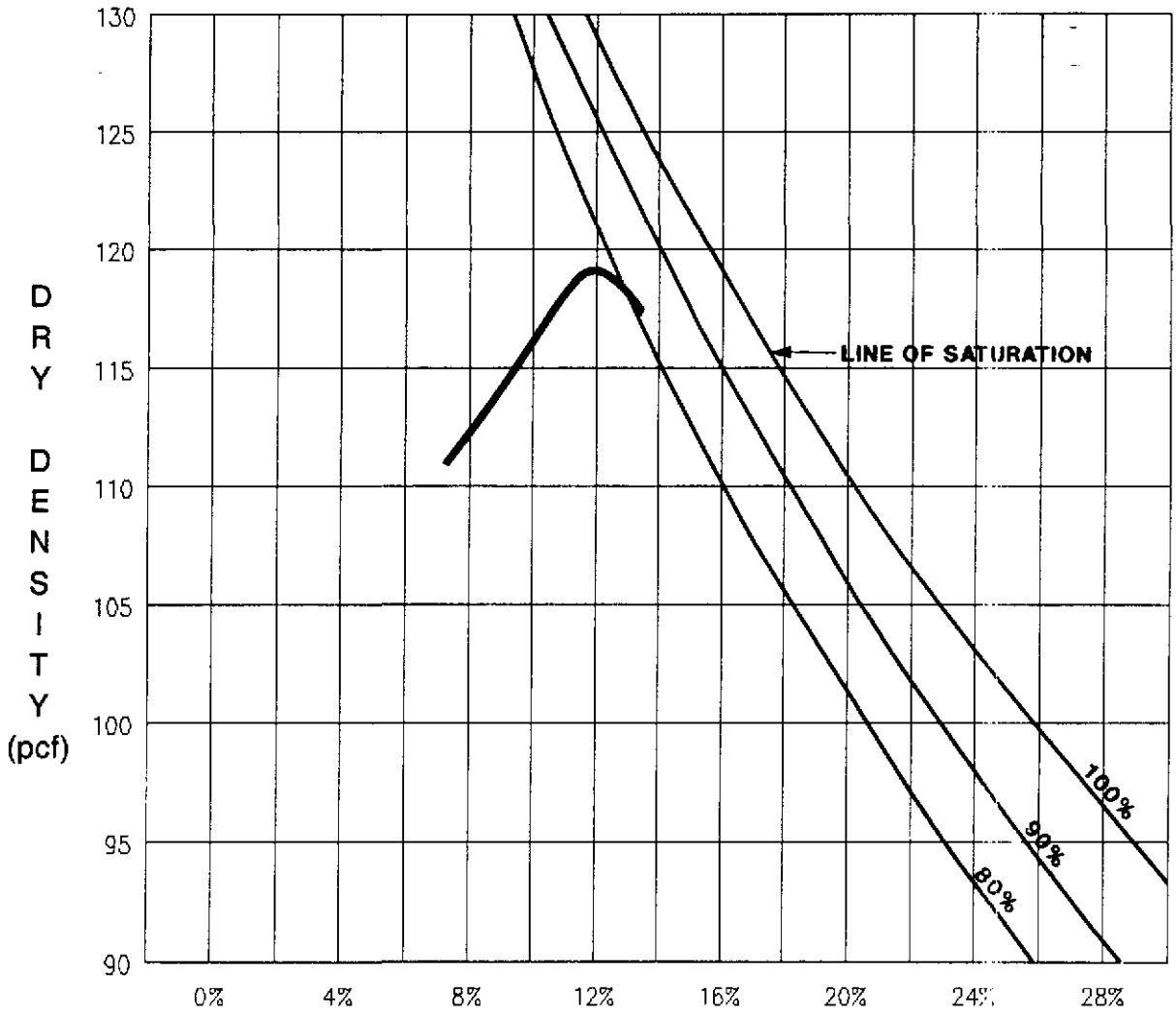
893-6255.10

GOLDER ASSOCIATES INC.
Consulting Engineers

Modified Proctor Moisture/Density Curves

MOISTURE/DRY DENSITY CURVE

ASTM D-1557



SAMPLE IDENTITY	Wn%	WL	WP	IP	DESCRIPTION
TOWNSEND SAND	4.0%	NP	NP	NP	Moderate yellowish brown m-f SAND,some f gravel, trace silt (SP)
	MAXIMUM DRY DENSITY (pcf)			119.0	(Gs=2.74)
	OPTIMUM MOISTURE (%)			12.0%	
SAMPLE TYPE	Bulk		DATE TESTED		5/23/90

ISRT/WOBURN/MA

893-6255.10

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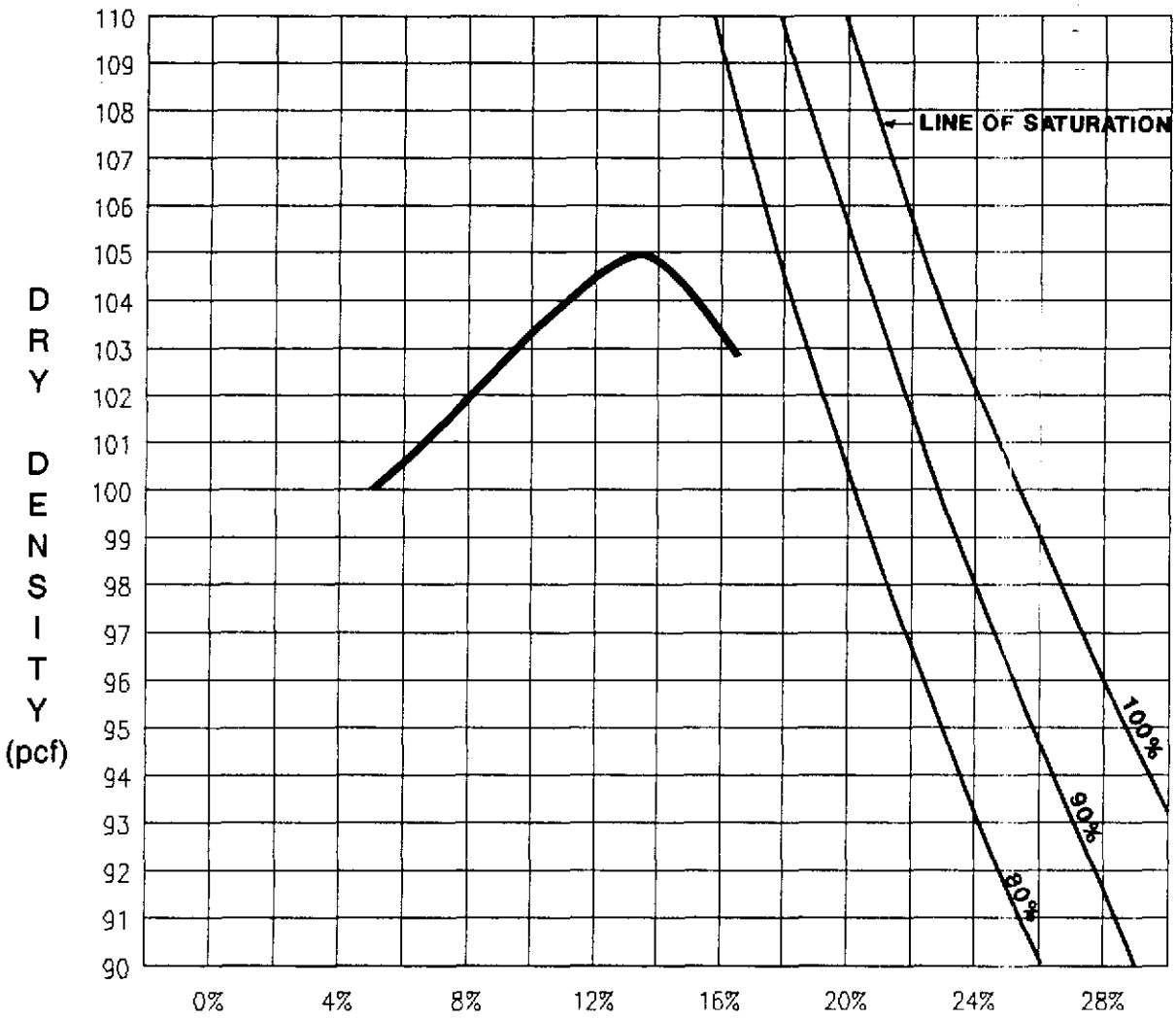
MOISTURE/DRY DENSITY CURVE

ASTM D-1557



MOISTURE CONTENT

SAMPLE IDENTITY	Wn%	WL	WP	IP	DESCRIPTION
ASHBURNHAM SAND	2.9%	NP	NP	NP	Moderate yellowish brown m-f SAND,trace silt (SP)
	MAXIMUM DRY DENSITY (pcf)			105.0	(Gs=2.70)
	OPTIMUM MOISTURE (%)			13.5%	
SAMPLE TYPE	Bulk		DATE TESTED		5/23/90

ISRT/WOBURN/MA

893-6255.10

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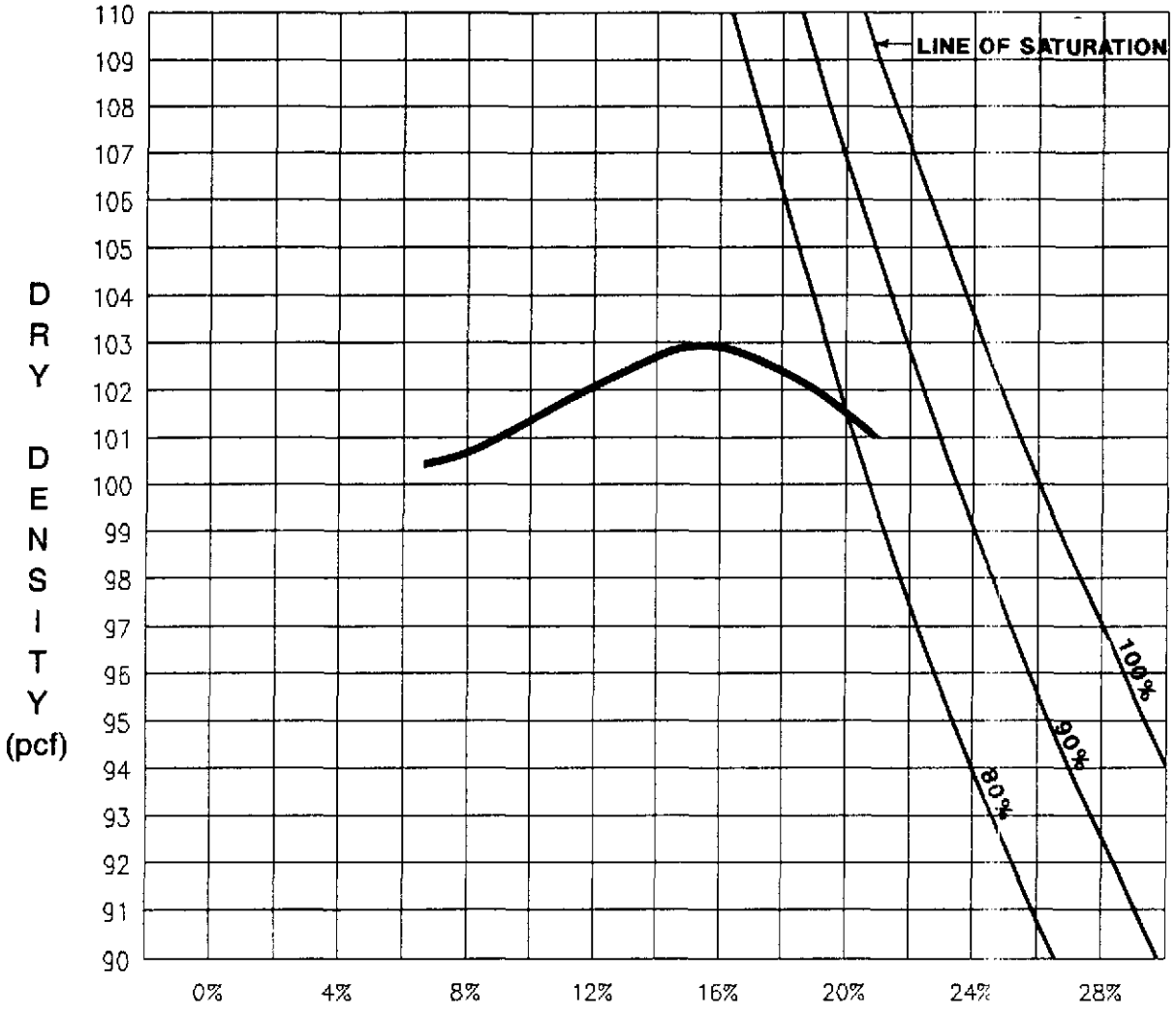
MOISTURE/DRY DENSITY CURVE

ASTM D-1557



SAMPLE IDENTITY	Wn%	WL	WP	IP	DESCRIPTION
WINCHENDON SAND	7.0%	NP	NP	NP	Yellowish brown f SAND,some silt (SM)
	MAXIMUM DRY DENSITY (pcf)			103.0	(Gs=2.75)
	OPTIMUM MOISTURE (%)			15.0%	
SAMPLE TYPE	Bulk		DATE TESTED		5/23/90

ISRT/WOBURN/MA

893-6255.10

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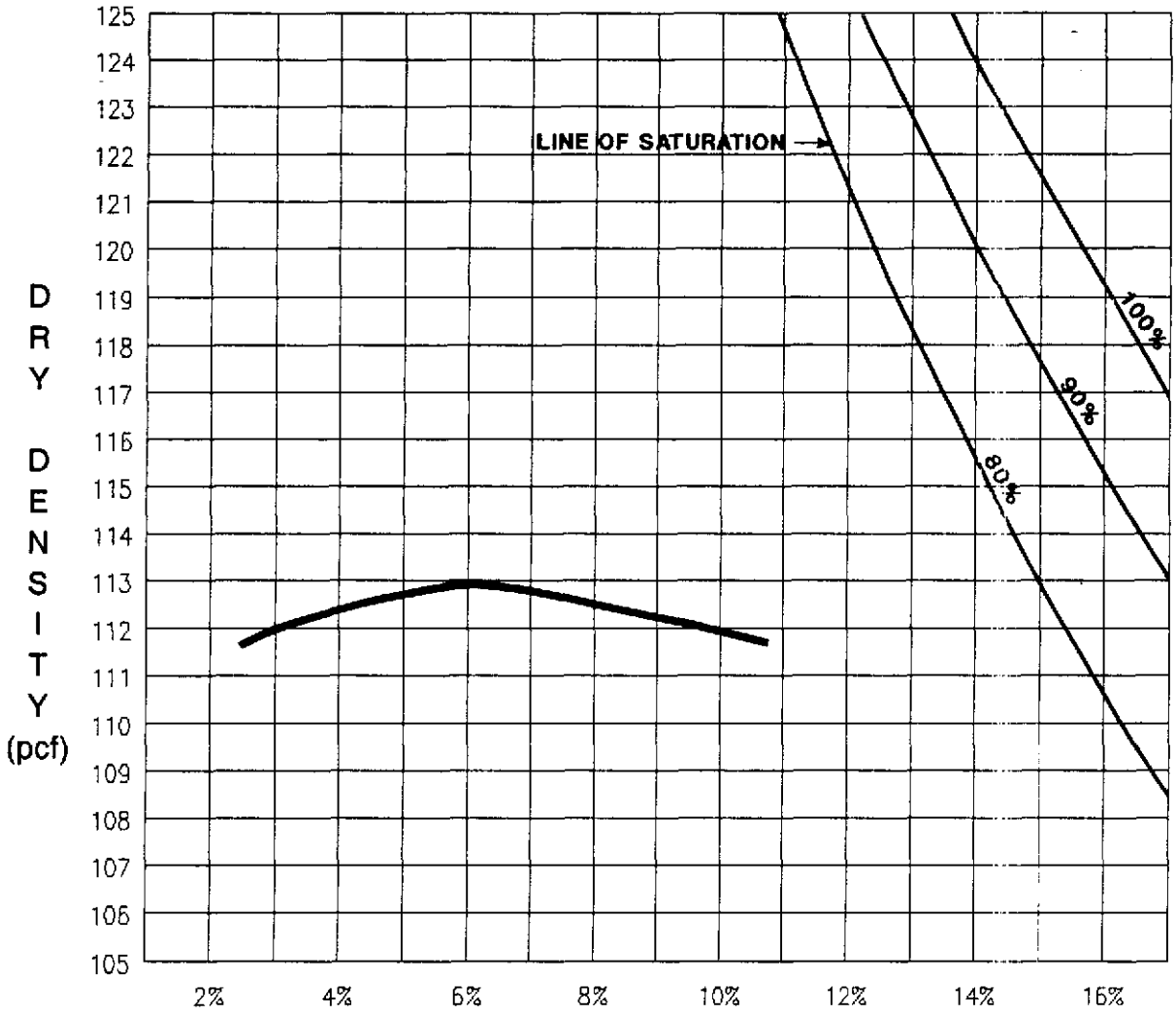
MOISTURE/DRY DENSITY CURVE

ASTM D-1557



SAMPLE IDENTITY	Wn%	WL	WP	IP	DESCRIPTION
HUBBARDSTON SAND	3.2%	NP	NP	NP	Dark yellowish orange c-f SAND,trace f gravel, trace silt (SP)
	MAXIMUM DRY DENSITY (pcf)			113.0	(Gs=2.75)
	OPTIMUM MOISTURE (%)			6.0%	
SAMPLE TYPE	Bulk		DATE TESTED		5/23/90

ISRT/WOBURN/MA

893-6255.10

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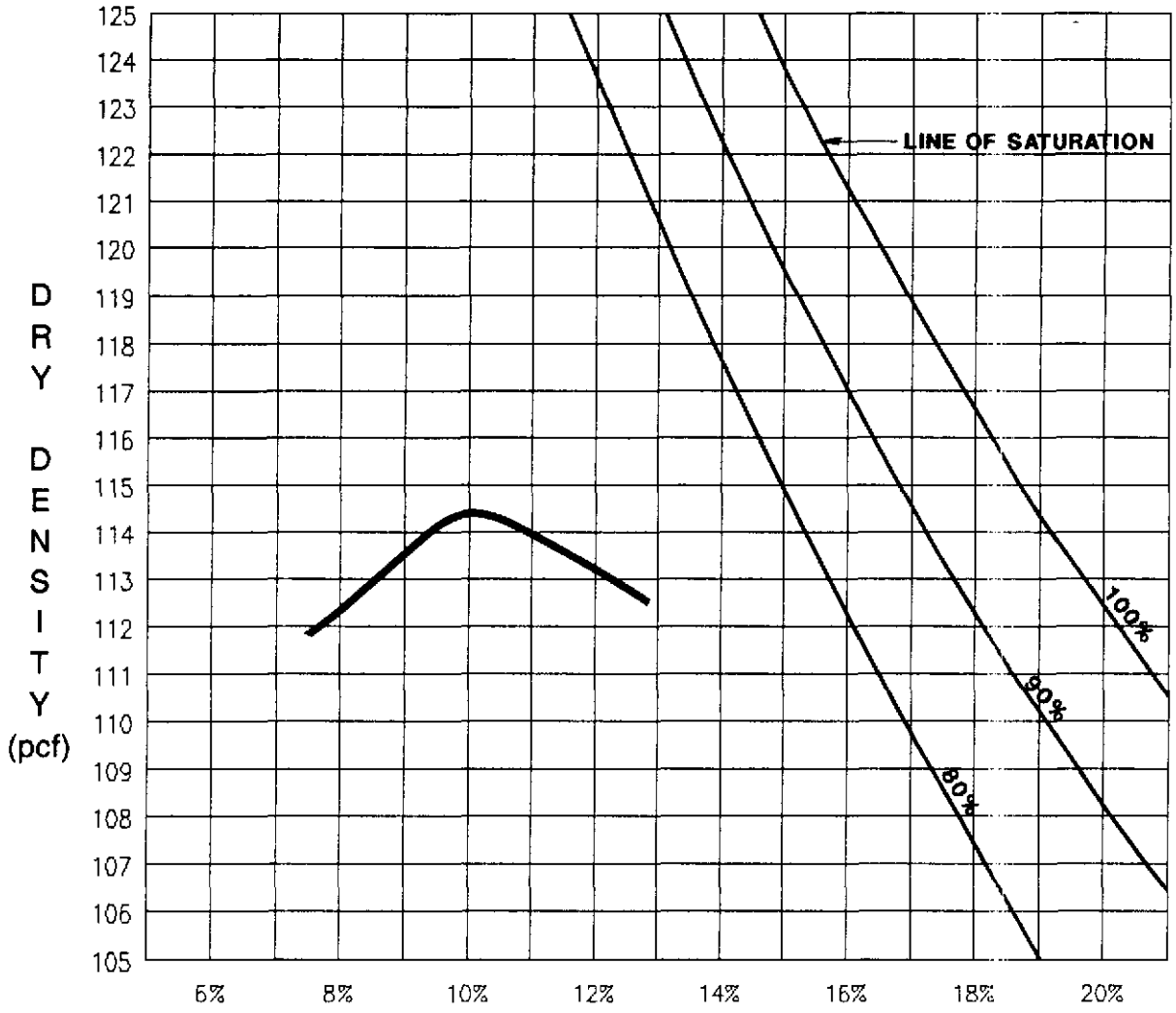
MOISTURE/DRY DENSITY CURVE

ASTM D-1557



SAMPLE IDENTITY	Wn%	WL	WP	IP	DESCRIPTION
HUBBARDSTON SAND/GRAVEL	6.6%	NP	NP	NP	Yellowish brown m-f SAND,little c-f gravel, little silt (SP-SM)
	MAXIMUM DRY DENSITY (pcf)			114.5	(Gs=2.82)
	OPTIMUM MOISTURE (%)			10.0%	
SAMPLE TYPE	Bulk		DATE TESTED		5/20/90

ISRT/WOBURN/MA

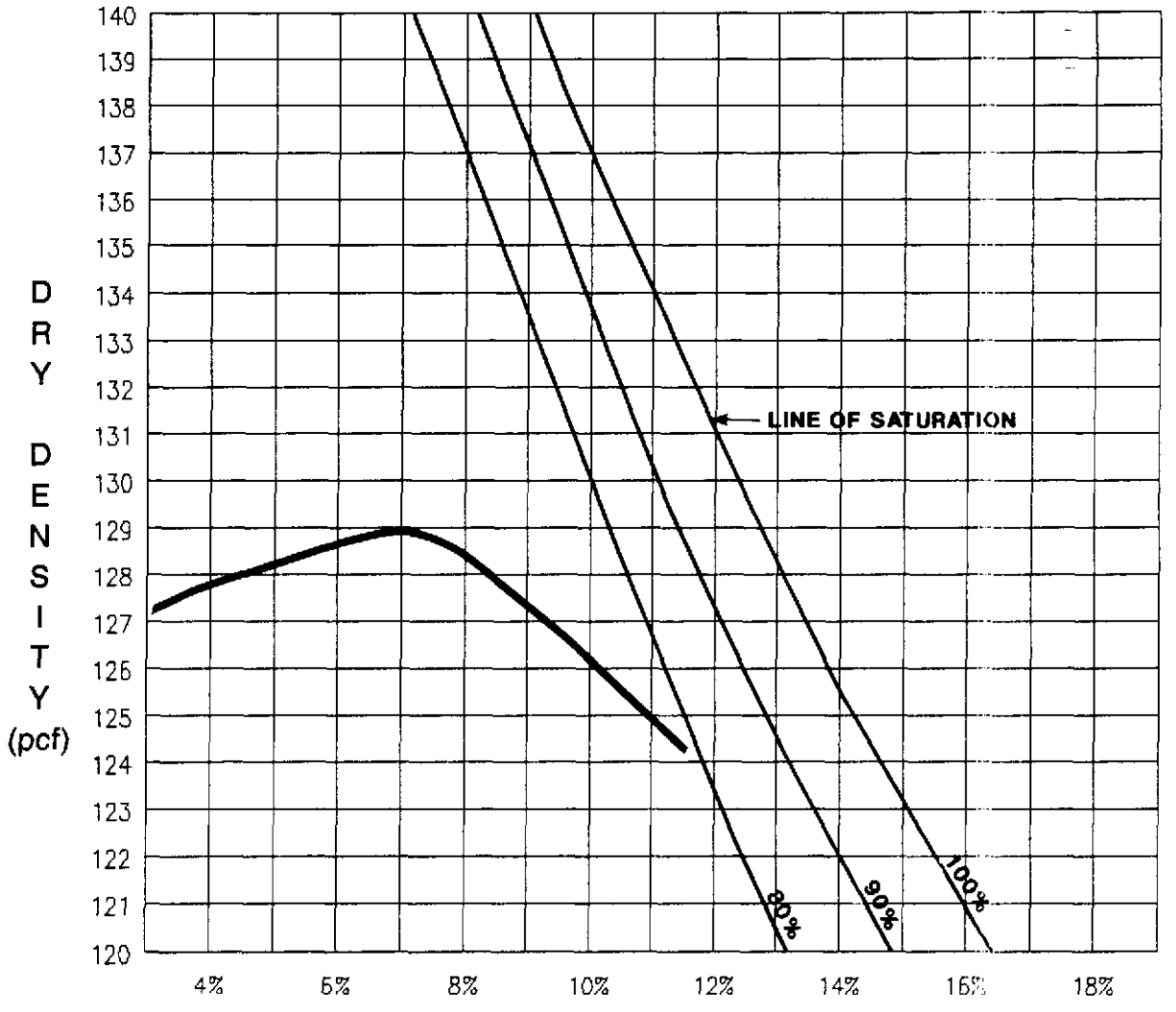
893-6255.10

GOLDER ASSOCIATES,INC

Consulting Engineers

MOISTURE/DRY DENSITY CURVE

ASTM D-1557



SAMPLE IDENTITY	Wn%	WL	WP	IP	DESCRIPTION
QUINN PERKINS PREPARED GRAVEL	5.6%	NP	NP	NP	Dark yellowish brown m-f SAND,some c-f gravel, little fines (SP-SM)
	MAXIMUM DRY DENSITY (pcf)			129.0	(Gs=2.81)
	OPTIMUM MOISTURE (%)			7.0%	
SAMPLE TYPE	Bulk		DATE TESTED		8/04/90

ISRT/WOBURN/MA

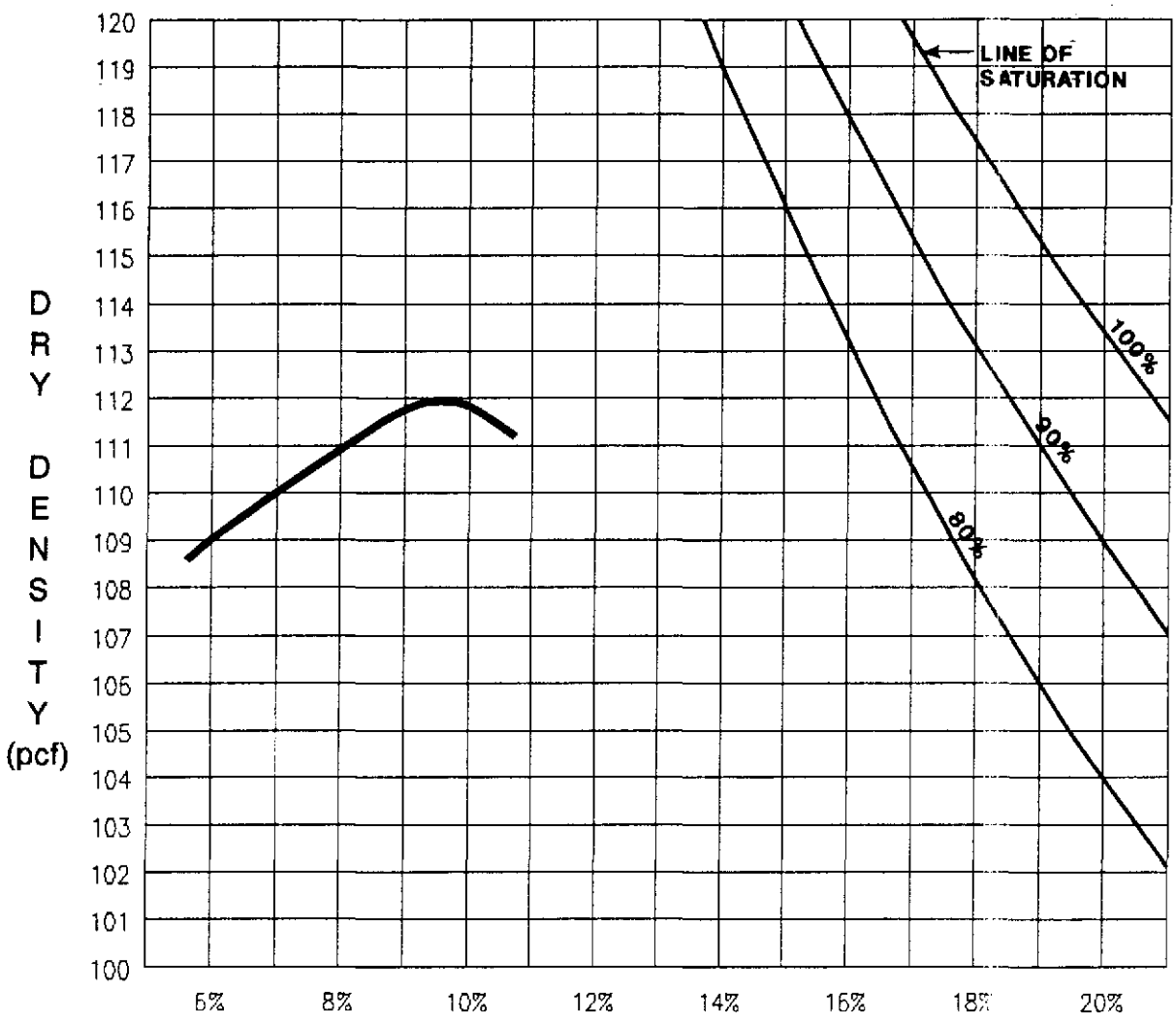
893-6255.10

GOLDER ASSOCIATES,INC

Consulting Engineers

MOISTURE/DRY DENSITY CURVE

ASTM D-1557



SAMPLE IDENTITY	Wn%	WL	WP	IP	DESCRIPTION
QUINN PERKINS CONCRETE SAND	2.2%	NP	NP	NP	Dark yellowish orange c-f SAND,trace silt, trace f gravel (SW) (Gs=2.85)
	MAXIMUM DRY DENSITY (pcf)			112.0	
	OPTIMUM MOISTURE (%)			9.5%	
SAMPLE TYPE	Bulk		DATE TESTED		8/04/90

ISRT/WOBURN/MA

893-6255.10

GOLDER ASSOCIATES,INC

Consulting Engineers

Rigid Wall Permeability

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: TK
PROJECT NUMBE 893-6255.10 DATE: 8/27/90

Sample Identification;

Number:	Townsend Sand
ID:	-
Type:	BULK
USCS:	SP/GP
Recieved:	8/16/90
Who:	JEW

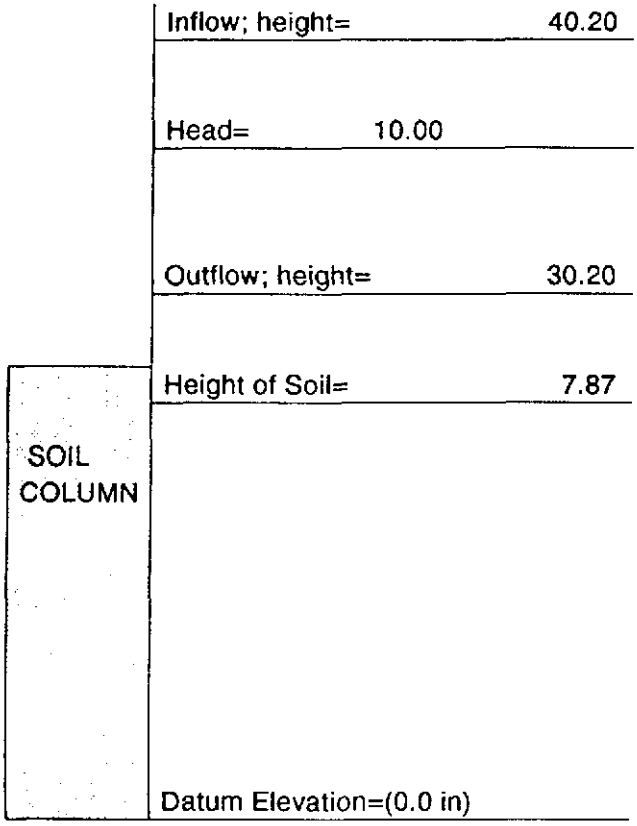
Density/Remolding Information

Proctor Density;	-
Max.Rel Density;	-
Min.Rel Density;	-
Desired Density;	max
Weight Soil Used;	2903.0
Moisture Content;	0.65

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a



PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	7.87	20.00
Height Inflow	40.20	102.11
Height Outflow	30.20	76.71
HEAD	10.00	25.40
Gradient	1.27	1.27
Diameter	4.00	10.16
Area	12.57	81.08
Volume	98.96	1621.60
Weight	6.40	2903.00
Calc Density	111.71	111.71

MOISTURE CONTENT

TARE NO.	c-2
Wt soil & tare,i	288.08
Wt soil & tare,f	287.45
Wt tare	190.18
Wt moisture	0.63
Wt dry soil	97.27
% MOISTURE	0.6%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	100.13	100.00
2	99.57	100.00
3	100.47	100.00
4	100.80	100.00
5	100.27	100.00
AVERAGE	100.25	100.00

FLOW PER UNIT OF TIME (cc/sec)	0.998
ALCULATION COEFFICIENT:	9.71E-03
VERAGE HYDRAULIC CONDUCTIVITY:	9.7E-03

ATE: 8/28/90 TECH: TK CHECK: TMS

CLCCI-P

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: ATLANTA
PROJECT NUMBE 89306255-10 DATE: 7/23/90

Sample Identification;

Number:	Ashburnham Sand
ID:	-
Type:	BULK
USCS:	SP
Recieved:	7/15/90
Who:	RJI

Density/Remolding Information

Proctor Density;	-
Max.Rel Density;	-
Min.Rel Density;	-
Desired Density;	max
Weight Soil Used;	9956.0
Moisture Content;	0.07

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a

	Inflow; height=	13.75
	Head=	13.75
	Outflow; height=	0.00
SOIL COLUMN	Height of Soil=	13.50
	Datum Elevation=(0.0 in)	

PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	13.50	34.29
Height Inflow	13.75	34.93
Height Outflow	0.00	0.00
HEAD	13.75	34.93
Gradient	1.02	1.02
Diameter	6.00	15.24
Area	28.27	182.41
Volume	381.70	6255.01
Weight	21.94	9956.00
Calc Density	99.32	99.32

MOISTURE CONTENT

TARE NO.	No #
Wt soil & tare,i	305.24
Wt soil & tare,f	305.06
Wt tare	43.26
Wt moisture	0.18
Wt dry soil	261.80
% MOISTURE	0.07%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	240.00	1046.00
2	240.00	1045.00
3	240.00	1045.00
4	240.00	1053.00
5	240.00	1045.00
AVERAGE	240.00	1046.80

LOW PER UNIT OF TIME (cc/sec)	4.362
CALCULATION COEFFICIENT:	5.38E-03
VERAGE HYDRAULIC CONDUCTIVITY:	2.3E-02

DATE: 8/29/90 TECH: ATLANTA CHECK: JMS

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: TK
PROJECT NUMBE 893-6255 DATE: 7/30/90

Sample Identification;

Number:	WINCHENDON SAND
ID:	
Type:	BULK
USCS:	SP
Recieved:	7/16/90
Who:	RG

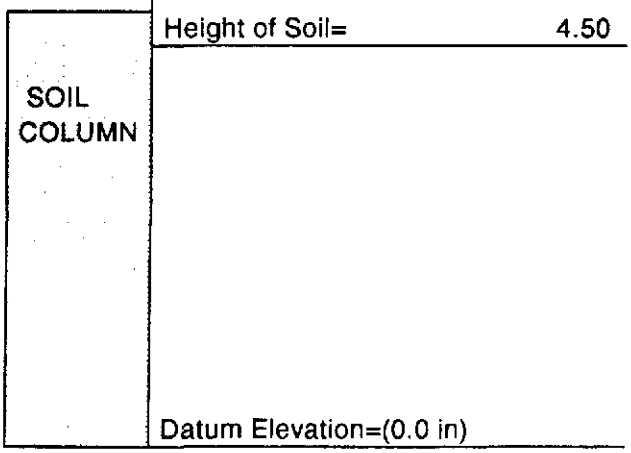
Density/Remolding Information

Proctor Density;	NA
Max.Rel Density;	NA
Min.Rel Density;	NA
Desired Density;	MAX
Weight Soil Used;	1283
Moisture Content;	0.3%

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a



PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	4.50	11.43
Height Inflow	42.10	106.93
Height Outflow	30.50	77.47
HEAD	11.60	29.46
Gradient	2.58	2.58
Diameter	4.00	10.16
Area	12.57	81.07
Volume	56.55	926.67
Weight	2.83	1283.00
Calc Density	86.39	86.39

MOISTURE CONTENT

TARE NO.	OVEN
Wt soil & tare,i	DRIED
Wt soil & tare,f	0.00
Wt tare	1.00
Wt moisture	0.00
Wt dry soil	-1.00
% MOISTURE	0.0%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	49.00	100.00
2	48.70	100.00
3	48.80	100.00
4	49.00	100.00
5	49.00	100.00
AVERAGE	48.90	100.00

FLOW PER UNIT OF TIME (cc/sec)	2.045
CALCULATION COEFFICIENT:	4.79E-03
AVERAGE HYDRAULIC CONDUCTIVITY:	9.8E-03

DATE: 7/30/90 TECH: TK CHECK: TMS

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MASS TECH: TK
PROJECT NUMBE 93-6255.10 DATE: 8/15/90

Sample Identification;

Number:	HUBBARDSTOWN SAND
ID:	-
Type:	BULK
USCS:	
Recieved:	8/13/90
Who:	TK

Density/Remolding Information

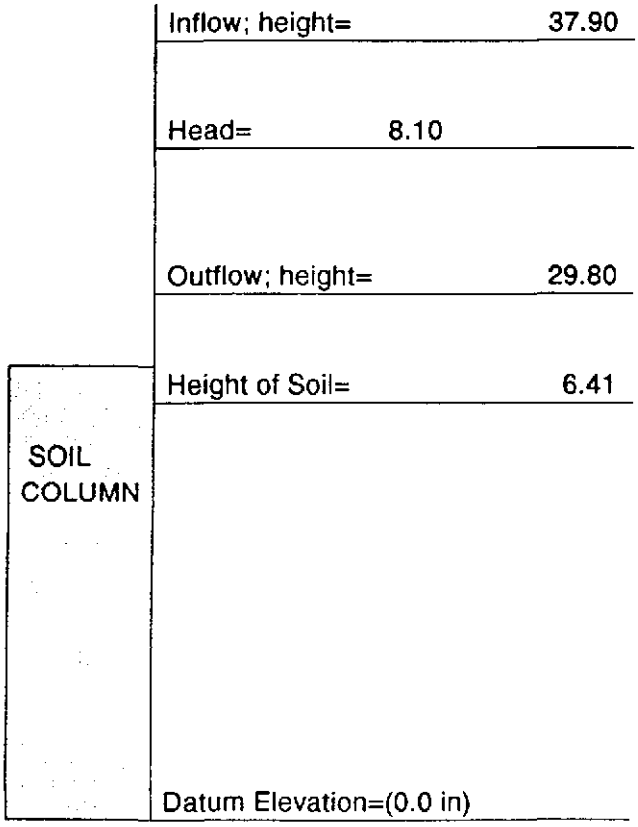
Proctor Density;	-
Max.Rel Density;	121.90
Min.Rel Density;	99.40
Desired Density;	120.80
Weight Soil Used;	2402
Moisture Content;	0.0%

Test Method; Constant Head

MAXIMUM ACHIEVABLE DENSITY: 113.6 pcf.

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a



PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	6.41	16.28
Height Inflow	37.90	96.27
Height Outflow	29.80	75.69
HEAD	8.10	20.57
Gradient	1.26	1.26
Diameter	4.00	10.16
Area	12.57	81.10
Volume	80.57	1320.54
Weight	5.29	2402.00
Calc Density	113.52	113.50

MOISTURE CONTENT

TARE NO.	0.00
Wt soil & tare,i	0.00
Wt soil & tare,f	0.00
Wt tare	0.00
Wt moisture	0.00
Wt dry soil	0.00
% MOISTURE	0.0%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	383.00	100.00
2	383.00	100.00
3	385.00	100.00
4	384.00	100.00
5	384.00	100.00
AVERAGE	383.80	100.00

FLOW PER UNIT OF TIME (cc/sec)	0.261
CALCULATION COEFFICIENT:	9.74E-03
AVERAGE HYDRAULIC CONDUCTIVITY:	2.5E-03

DATE: 8/10/90 TECH: TK CHECK:

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: TK
PROJECT NUMBE 893-6255 DATE: 7/30/90

ample Identification;

Number:	HUBBARD
ID:	SAND/GRAVEL
Type:	BULK
USCS:	SP-GP
Recieved:	7/16/90
Who:	RG

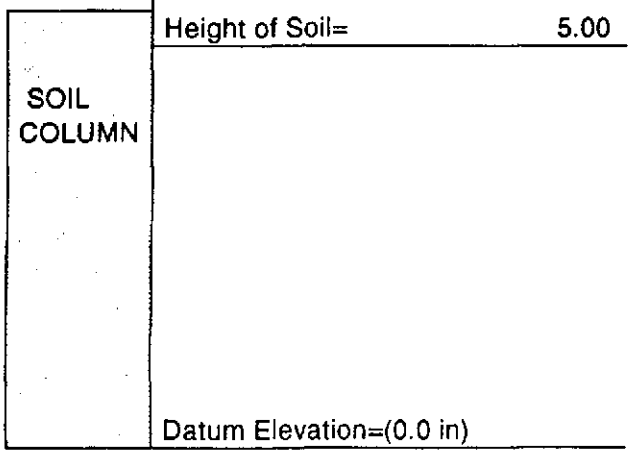
Density/Remolding Information

Proctor Density;	NA
Max.Rel Density;	NA
Min.Rel Density;	NA
Desired Density;	MAX
Weight Soil Used;	1685
Moisture Content;	14.6%

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a



PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	5.00	12.70
Height Inflow	42.00	106.68
Height Outflow	31.00	78.74
HEAD	11.00	27.94
Gradient	2.20	2.20
Diameter	4.00	10.16
Area	12.57	81.07
Volume	62.83	1029.63
Weight	3.71	1685.00
Calc Density	102.12	102.12

MOISTURE CONTENT

TARE NO.	E-032
Wt soil & tare,i	118.90
Wt soil & tare,f	107.90
Wt tare	32.10
Wt moisture	11.00
Wt dry soil	75.80
% MOISTURE	14.5%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	240.00	57.00
2	240.00	49.00
3	240.00	45.00
4	240.00	41.00
5	240.00	39.00
AVERAGE	240.00	46.20

FLOW PER UNIT OF TIME (cc/sec)	0.193
ALCULATION COEFFICIENT:	5.61E-03
AVERAGE HYDRAULIC CONDUCTIVITY:	1.1E-03

ATE: 7/30/90 TECH: TK CHECK: TMS

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: TK
ROJECT NUMBE 893-6255 DATE: 7/30/90

Sample Identification;

Number:	QUINN PERKINS
ID:	PREPARED
Type:	GRAVEL
USCS:	GP
Recieved:	7/16/90
Who:	RG

Density/Remolding Information

Proctor Density;	NA
Max.Rel Density;	NA
Min.Rel Density;	NA
Desired Density;	MAX
Weight Soil Used;	1590
Moisture Content;	0.0%

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a

Inflow; height=	39.40
Head=	8.80
Outflow; height=	30.60
Height of Soil=	4.50

SOIL COLUMN

Datum Elevation=(0.0 in)

PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	4.50	11.43
Height Inflow	39.40	100.08
Height Outflow	30.60	77.72
HEAD	8.80	22.36
Gradient	1.96	1.96
Diameter	4.00	10.16
Area	12.57	81.07
Volume	56.55	926.67
Weight	3.50	1590.00
Calc Density	107.07	107.07

MOISTURE CONTENT

TARE NO.	OVEN
Wt soil & tare,i	DRIED
Wt soil & tare,f	0.00
Wt tare	1.00
Wt moisture	0.00
Wt dry soil	-1.00
% MOISTURE	0.0%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	360.00	41.00
2	360.00	37.00
3	360.00	32.50
4	360.00	29.00
5	360.00	26.00
AVERAGE	360.00	33.10

OW PER UNIT OF TIME (cc/sec)	0.092
ALCULATION COEFFICIENT:	6.31E-03
AVERAGE HYDRAULIC CONDUCTIVITY:	5.8E-04

ATE: 7/30/90 TECH: TK CHECK: TMS

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: TK
PROJECT NUMBE 893-6255 DATE: 7/30/90

Sample Identification;

Number:	QUINN PERKINS
ID:	CONCRETE SAND
Type:	BULK
USCS:	SP
Recieved:	7/16/90
Who:	RG

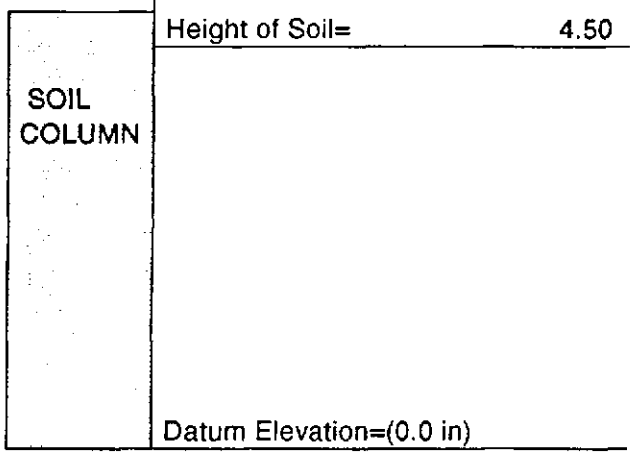
Density/Remolding Information

Proctor Density;	NA
Max.Rel Density;	NA
Min.Rel Density;	NA
Desired Density;	MAX
Weight Soil Used;	1539
Moisture Content;	1.6%

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a



PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	4.50	11.43
Height Inflow	41.20	104.65
Height Outflow	29.50	74.93
HEAD	11.70	29.72
Gradient	2.60	2.60
Diameter	4.00	10.16
Area	12.57	81.07
Volume	56.55	926.67
Weight	3.39	1539.00
Calc Density	103.63	103.63

MOISTURE CONTENT

TARE NO.	E-026
Wt soil & tare,i	136.99
Wt soil & tare,f	135.34
Wt tare	32.18
Wt moisture	1.65
Wt dry soil	103.16
% MOISTURE	1.6%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	49.30	100.00
2	49.70	100.00
3	49.40	100.00
4	49.60	100.00
5	49.70	100.00
AVERAGE	49.54	100.00

FLOW PER UNIT OF TIME (cc/sec)	2.019
CALCULATION COEFFICIENT:	4.74E-03
AVERAGE HYDRAULIC CONDUCTIVITY:	9.6E-03

DATE: 7/30/90 TECH: TK CHECK: TMS

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: TK
PROJECT NUMBE 893-6255 DATE: 7/30/90

ample Identification;

Number:	QUINN PERKINS
ID:	3/8" STONE
Type:	BULK
USCS:	GP
Recieved:	7/16/90
Who:	RG

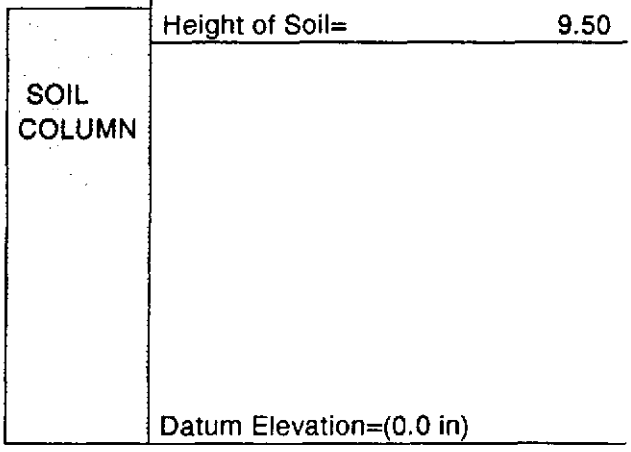
Density/Remolding Information

Proctor Density;	NA
Max.Rel Density;	NA
Min.Rel Density;	NA
Desired Density;	MAX
Weight Soil Used;	3059
Moisture Content;	0.0%

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a



PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	9.50	24.13
Height Inflow	38.00	96.52
Height Outflow	31.10	78.99
HEAD	6.90	17.53
Gradient	0.73	0.73
Diameter	4.00	10.16
Area	12.57	81.07
Volume	119.38	1956.29
Weight	6.74	3059.00
Calc Density	97.57	97.57

MOISTURE CONTENT

TARE NO.	OVEN
Wt soil & tare,i	DRIED
Wt soil & tare,f	0.00
Wt tare	1.00
Wt moisture	0.00
Wt dry soil	-1.00
% MOISTURE	0.0%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	106.40	100.00
2	106.70	100.00
3	106.30	100.00
4	106.70	100.00
5	106.30	100.00
AVERAGE	106.48	100.00

FLOW PER UNIT OF TIME (cc/sec)	0.939
ALCULATION COEFFICIENT:	1.70E-02
AVERAGE HYDRAULIC CONDUCTIVITY:	1.6E-02

ATE: 7/30/90 TECH: TK CHECK: TMS

CLCCHP

CONSTANT HEAD RIGID WALL PERMEABILITY
COE EM-1110-2-1906 APPENDIX VII
GOLDER ASSOCIATES, PHILADELPHIA

PROJECT TITLE: ISRT/WOBURN/MA TECH: TK
PROJECT NUMBE 893-6255 DATE: 7/30/90

ample Identification:

Number:	QUINN PERKINS
ID:-	3/4" STONE
Type:	BULK
USCS:	GP
Recieved:	7/16/90
Who:	RG

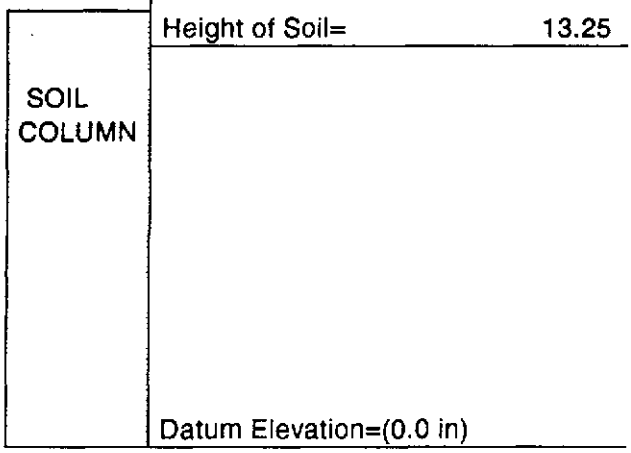
Density/Remolding Information

Proctor Density;	NA
Max.Rel Density;	NA
Min.Rel Density;	NA
Desired Density;	MAX
Weight Soil Used;	3925
Moisture Content;	0.0%

Test Method; Constant Head

Using Q=kia; where Q=quanity of flow ,per unit of time
k=coefficient of hydraulic conductivity
i=gradient
a=area of permeameter

so q/dt=kia=k(dh/l)a



PERMEABILITY DATA

Parameter	(inches)	(cm)
Height Soil	13.25	33.66
Height Inflow	38.90	98.81
Height Outflow	30.50	77.47
HEAD	8.40	21.34
Gradient	0.63	0.63
Diameter	4.00	10.16
Area	12.57	81.07
Volume	166.53	2728.92
Weight	8.65	3925.00
Calc Density	89.75	89.75

MOISTURE CONTENT

TARE NO.	OVEN
Wt soil & tare,i	DRIED
Wt soil & tare,f	0.00
Wt tare	1.00
Wt moisture	0.00
Wt dry soil	-1.00
% MOISTURE	0.0%

PERMEABILITY RUNS

RUN NO.	TIME(sec)	FLOW (cc)
1	55.70	100.00
2	54.10	100.00
3	55.20	100.00
4	54.30	100.00
5	54.10	100.00
AVERAGE	54.68	100.00

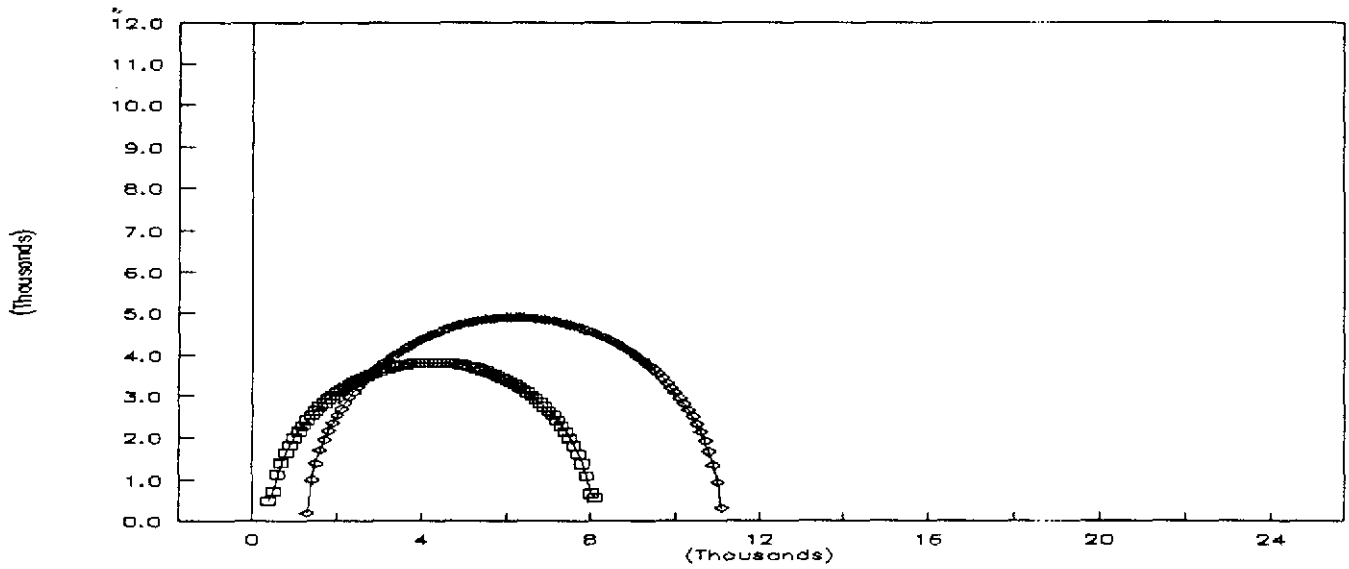
FLOW PER UNIT OF TIME (cc/sec)	1.829
ALCULATION COEFFICIENT:	1.95E-02
AVERAGE HYDRAULIC CONDUCTIVITY:	3.6E-02

ATE: 7/30/90 TECH: TK CHECK: TMS

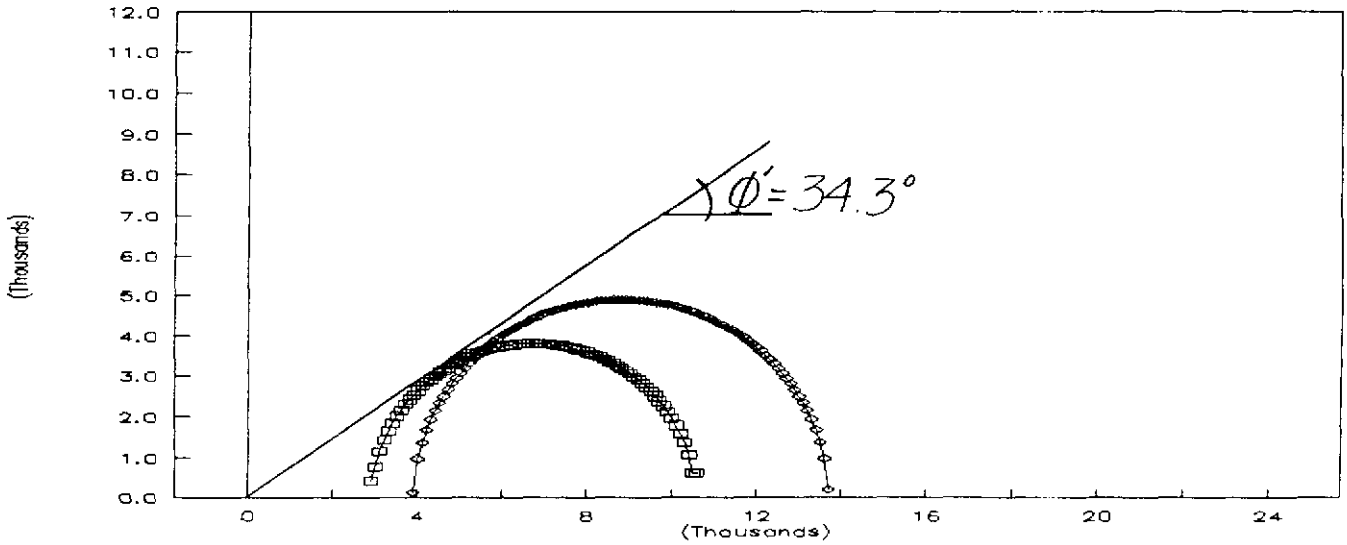
Shear Strength Tests

TRIAXIAL COMPRESSION STRENGTH TEST
CONSOLIDATED/UNDRAINED WITH PORE PRESSURE MEASUREMENT
WINCHENDON SAND

TOTAL STRESS MOHR'S STRENGTH CIRCLES (in psf)



EFFECTIVE STRESS MOHR'S STRENGTH CIRCLES (in psf)



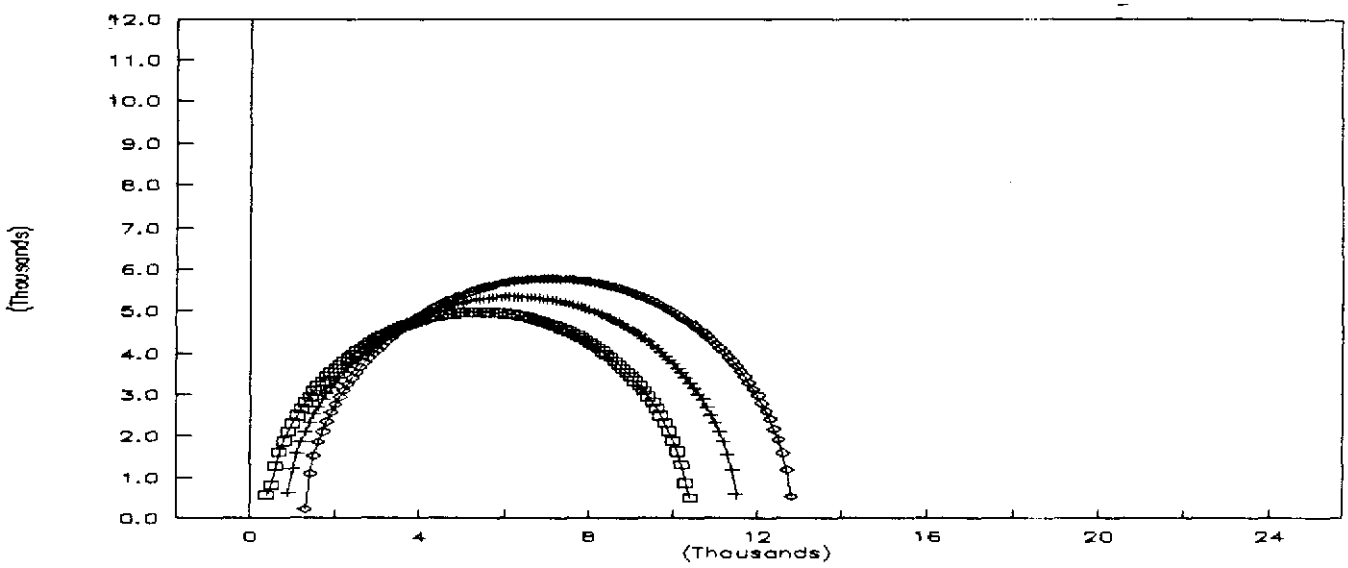
Consolidation Pressure	Initial Moisture	Initial Moist Density
(psi)	(%)	(pcf)
3	13.5	109.0
6	–	–
9	18.6	114.0

ISRT/WOBURN/MA
893-6255.10

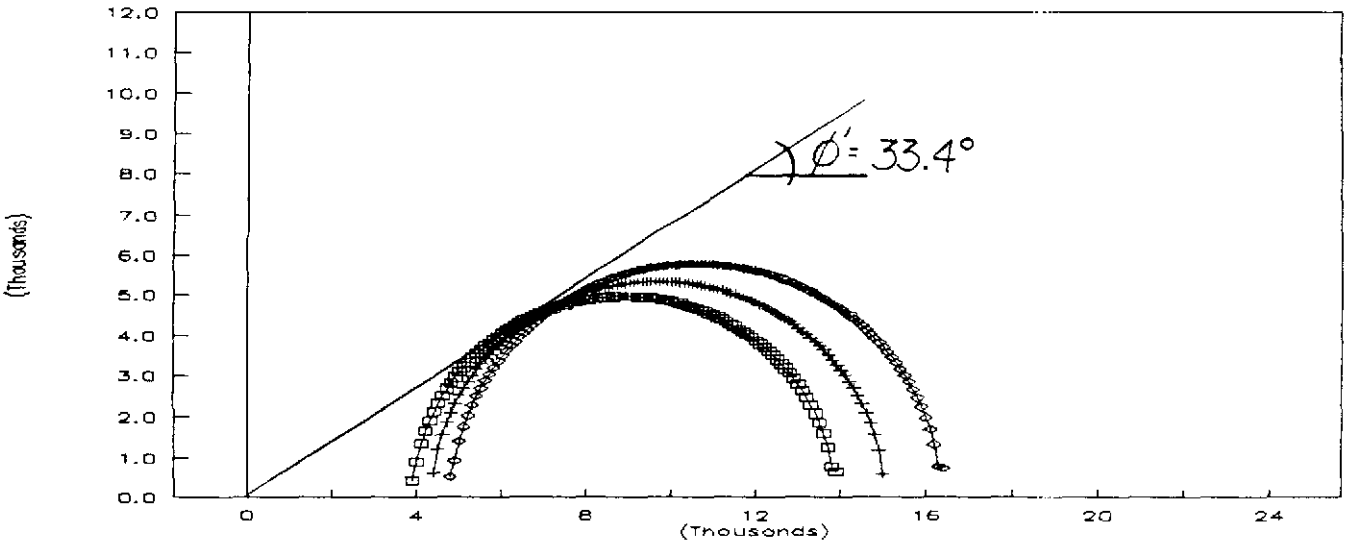
GOLDER ASSOCIATES INC.
MT. LAUREL, N.J.

TRIAXIAL COMPRESSION STRENGTH TEST
CONSOLIDATED/UNDRAINED WITH PORE PRESSURE MEASUREMENT
ASHBURNHAM SAND

TOTAL STRESS MOHR'S STRENGTH CIRCLES (in psf)



EFFECTIVE STRESS MOHR'S STRENGTH CIRCLES (in psf)



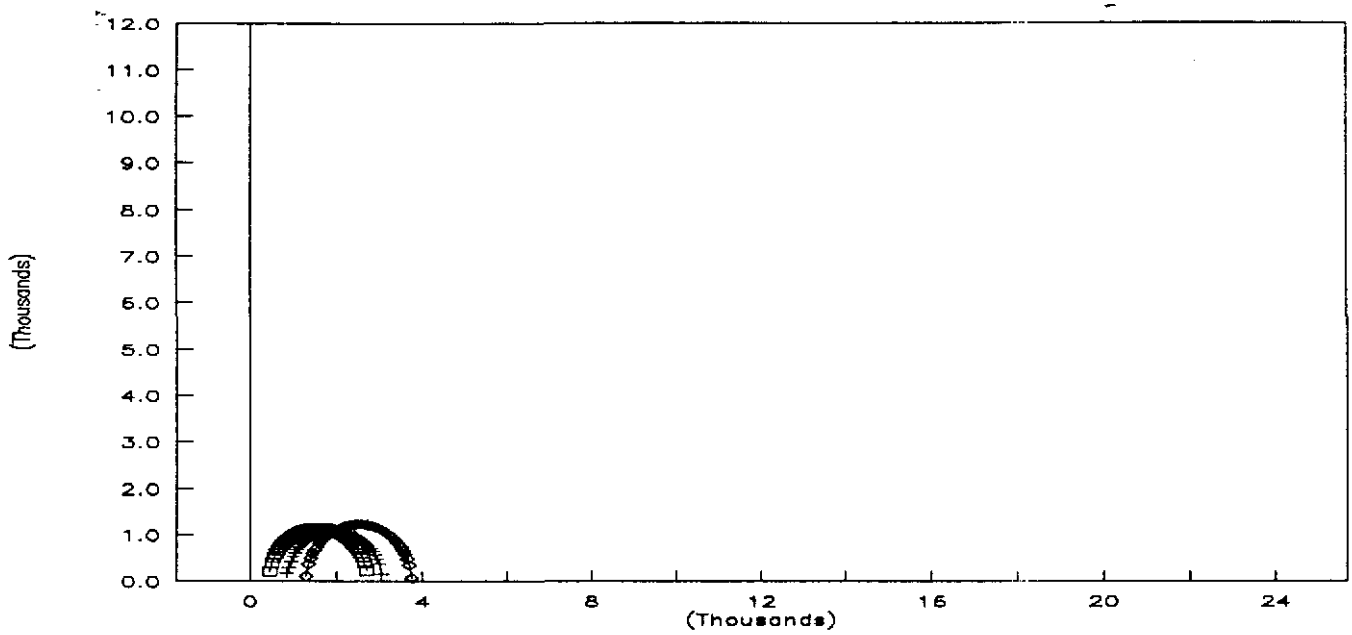
Consolidation Pressure	Initial Moisture	Initial Moist Density
(psi)	(%)	(pcf)
3	13.9	113.4
6	14.5	114.0
9	14.0	113.5

ISRT/WOBURN/MA
893-6255.10

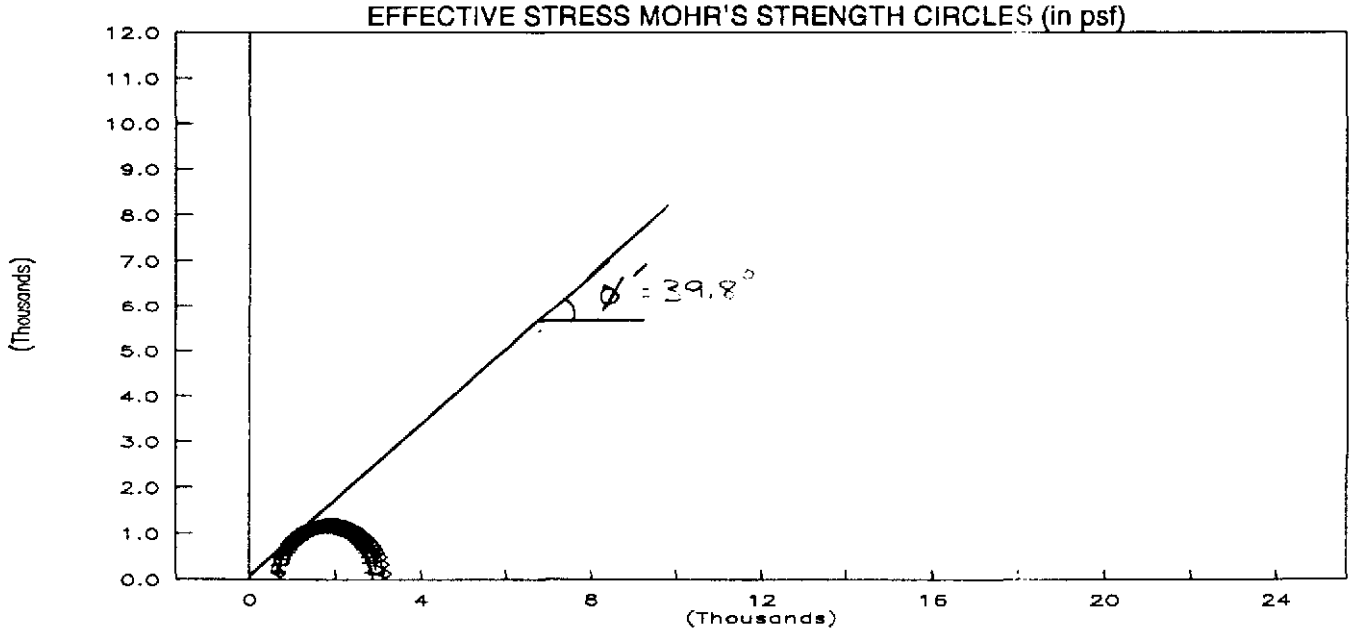
GOLDER ASSOCIATES INC.
MT. LAUREL, N.J.

TRIAXIAL COMPRESSION STRENGTH TEST
CONSOLIDATED/UNDRAINED WITH PORE PRESSURE MEASUREMENT
HUBBARDSTON SAND

TOTAL STRESS MOHR'S STRENGTH CIRCLES (in psf)



EFFECTIVE STRESS MOHR'S STRENGTH CIRCLES (in psf)



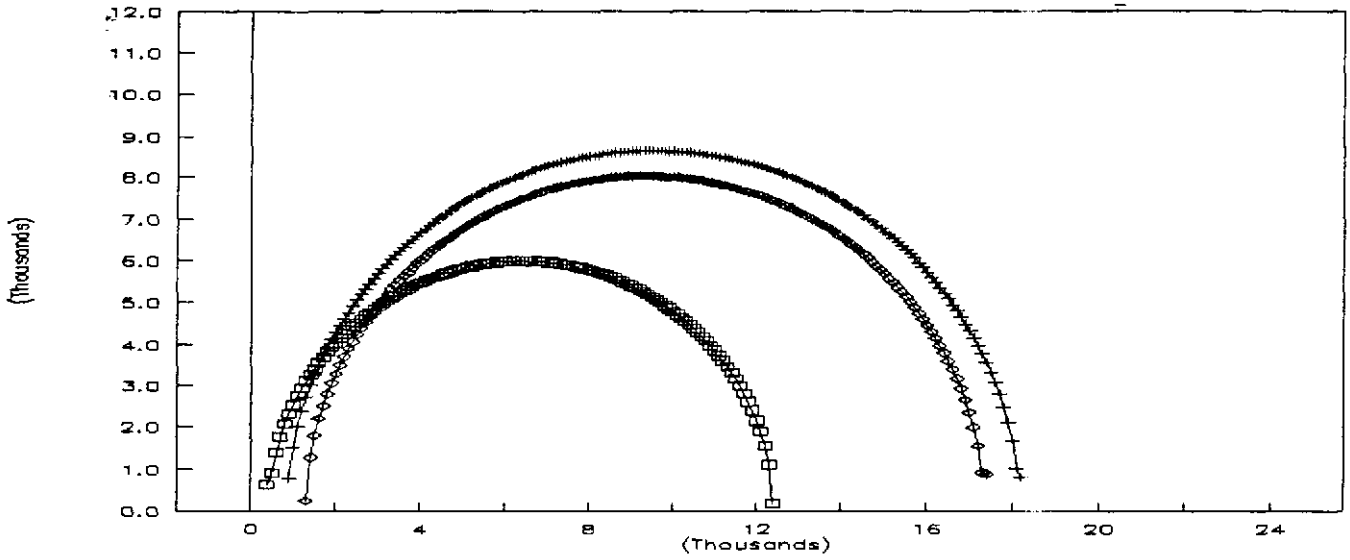
Consolidation Pressure	Initial Moisture	Initial Moist Density
(psi)	(%)	(pcf)
3	5.7	113.2
6	5.7	111.0
9	5.7	112.0

ISRT/WOBURN/MA
893-6255.10

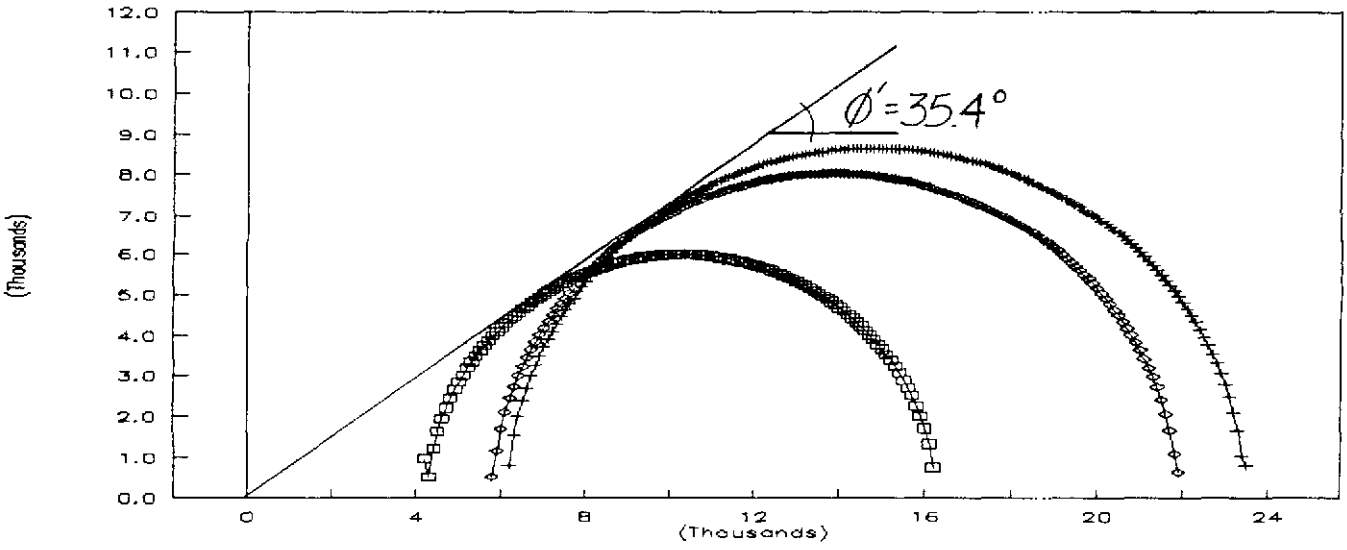
GOLDER ASSOCIATES INC.
MT. LAUREL, N.J.

TRIAXIAL COMPRESSION STRENGTH TEST
CONSOLIDATED/UNDRAINED WITH PORE PRESSURE MEASUREMENT
HUBBARDSTON SAND AND GRAVEL

TOTAL STRESS MOHR'S STRENGTH CIRCLES (in psf)



EFFECTIVE STRESS MOHR'S STRENGTH CIRCLES (in psf)



Consolidation Pressure	Initial Moisture	Initial Moist Density
(psi)	(%)	(pcf)
3	11.7	119.3
6	11.0	119.1
9	10.9	119.0

ISRT/WOBURN/MA
893-6255.10

GOLDER ASSOCIATES INC.
MT. LAUREL, N.J.

Consolidation Tests

CONSOLIDATION TEST

FIGURE

PROJECT ISRT/Woburn/MA

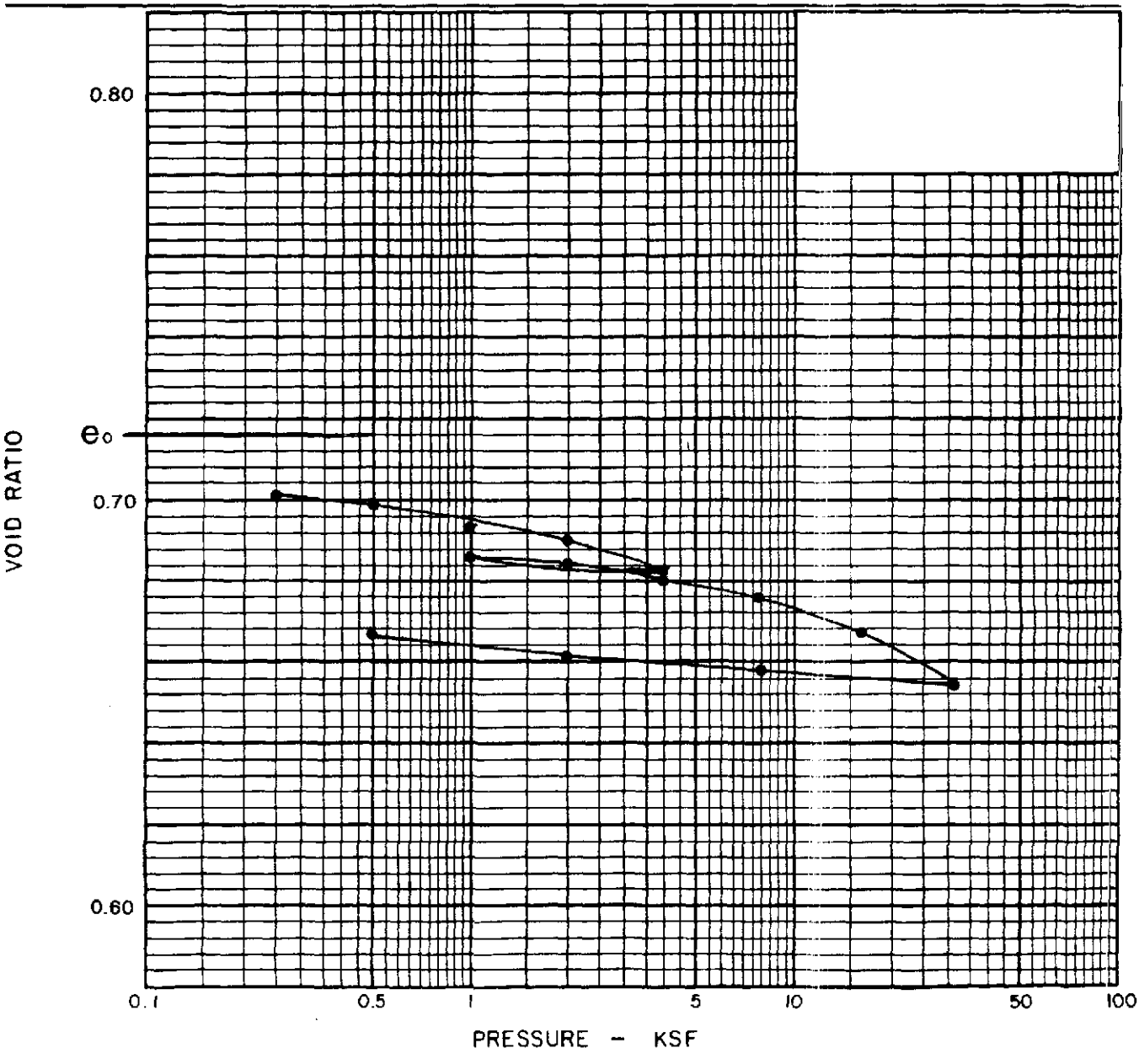
BORING NO. _____ SAMPLE NO. _____ DEPTH _____ ELEV. _____

DESCRIPTION Ashburnham Sand

INITIAL SAMPLE HEIGHT	0.750 IN.	SAMPLE AREA	4.923 SQ. IN.	SPECIFIC GRAVITY	2.70
INITIAL MOISTURE CONTENT	13.92 %	INITIAL BULK DENSITY	111.88 PCF	INITIAL DRY DENSITY	98.21 PCF
INITIAL VOID RATIO	0.716	INITIAL SATURATION	52.5 %	FINAL SATURATION	100.0 %

ATTERBERG LIMITS: L_w _____ % I_w _____ % P_w NP %

REMARKS: _____



Scale AS SHOWN
Date 9-6-90
Job No. 893-6255

Golder Associates

Drawn RT
Checked RJI
Reviewed PCR

CONSOLIDATION TEST

FIGURE

PROJECT ISRT/Woburn/MA

BORING NO. _____ SAMPLE NO. _____ DEPTH _____ ELEV. _____

DESCRIPTION Hubbardston Sand and Gravel

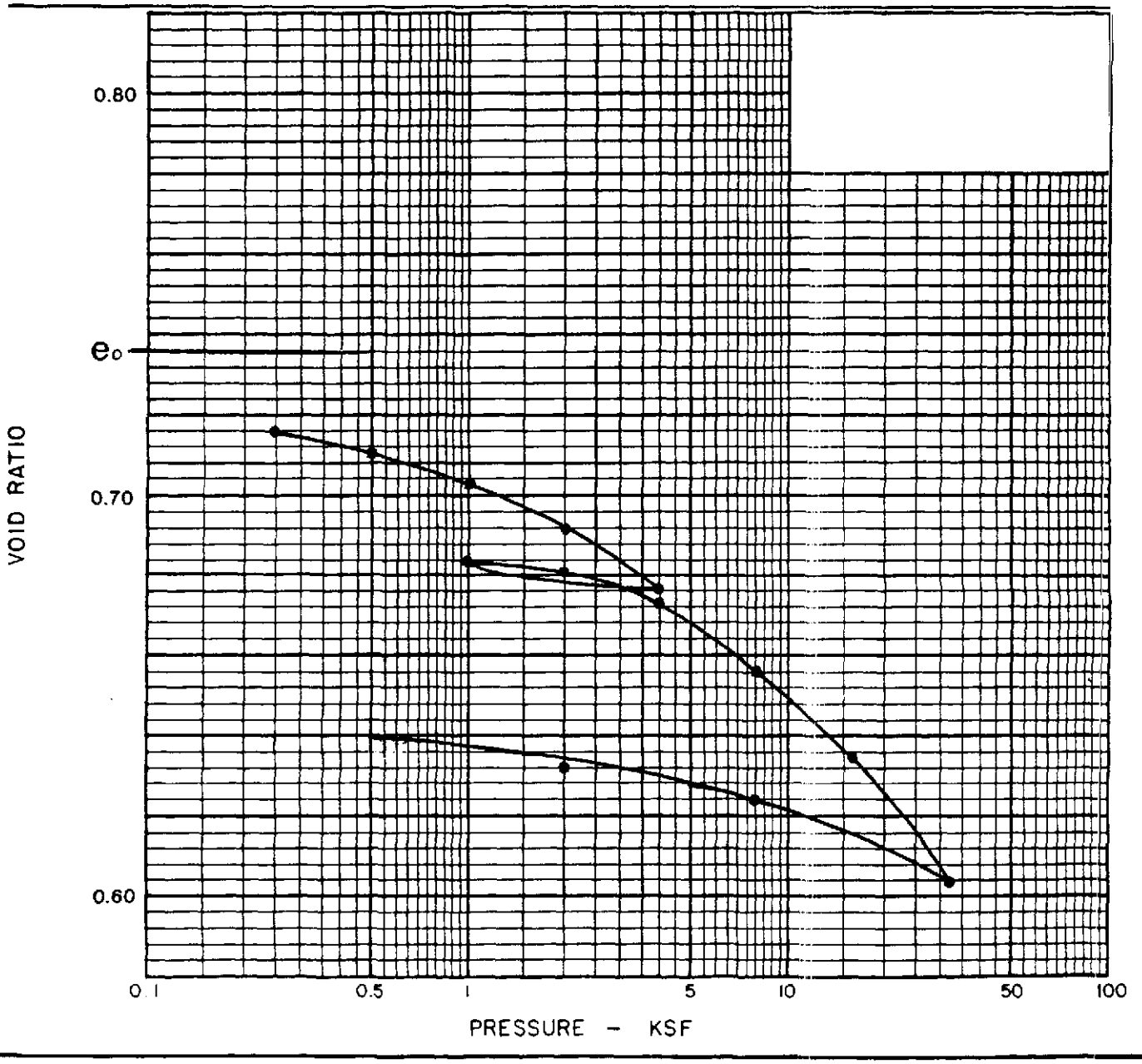
INITIAL SAMPLE HEIGHT 0.747 IN. SAMPLE AREA 4.893 SQ. IN. SPECIFIC GRAVITY 2.82±

INITIAL MOISTURE CONTENT 11.52 % INITIAL BULK DENSITY 112.56 PCF INITIAL DRY DENSITY 101.43 PCF

INITIAL VOID RATIO 0.736 INITIAL SATURATION 42.0 % FINAL SATURATION 100.0 %

ATTERBERG LIMITS: L_w ___ % I_w ___ % P_w NP %

REMARKS: _____



Scale AS SHOWN
Date 9-6-90
Job No. 893-6255

Golder Associates

Drawn RT
Checked RJI
Reviewed PCR

CONSOLIDATION TEST

FIGURE

PROJECT ISRT/Woburn/MA

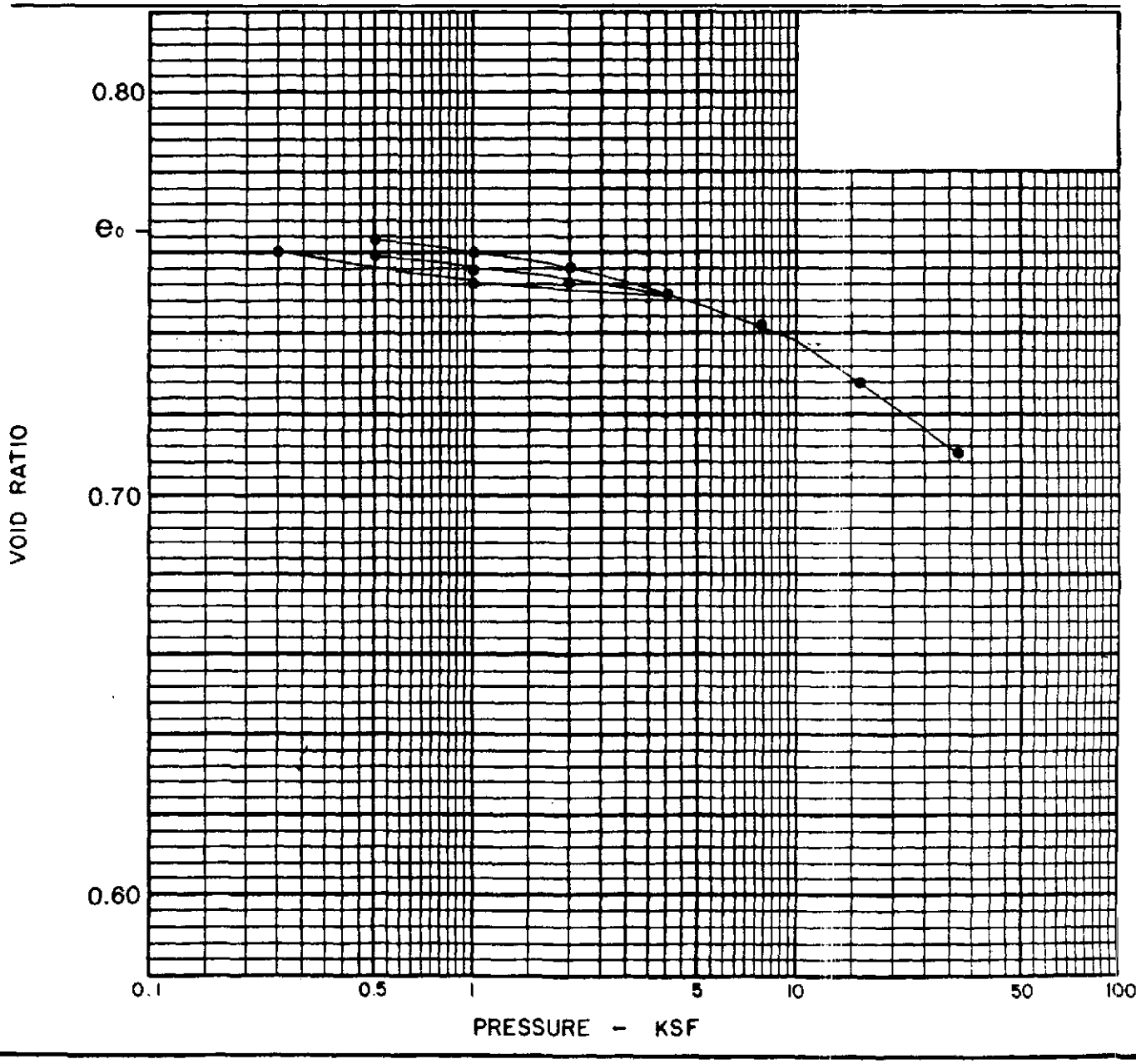
BORING NO. _____ SAMPLE NO. _____ DEPTH _____ ELEV. _____

DESCRIPTION Winchendon Sand

INITIAL SAMPLE HEIGHT	0.759 IN.	SAMPLE AREA	4.893 SQ. IN.	SPECIFIC GRAVITY	2.75
INITIAL MOISTURE CONTENT	7.45 %	INITIAL BULK DENSITY	104.43 PCF	INITIAL DRY DENSITY	97.19 PCF
INITIAL VOID RATIO	0.765	INITIAL SATURATION	26.7 %	FINAL SATURATION	100.0 %

ATTERBERG LIMITS: L_w _____ % I_w _____ % P_w NP %

REMARKS: _____



Scale AS SHOWN
Date 9-6-90
Job No. 893-655

Golder Associates

Drawn LAS
Checked RJI
Reviewed PCR

CONSOLIDATION TEST

FIGURE

PROJECT ISRT/Woburn/MA

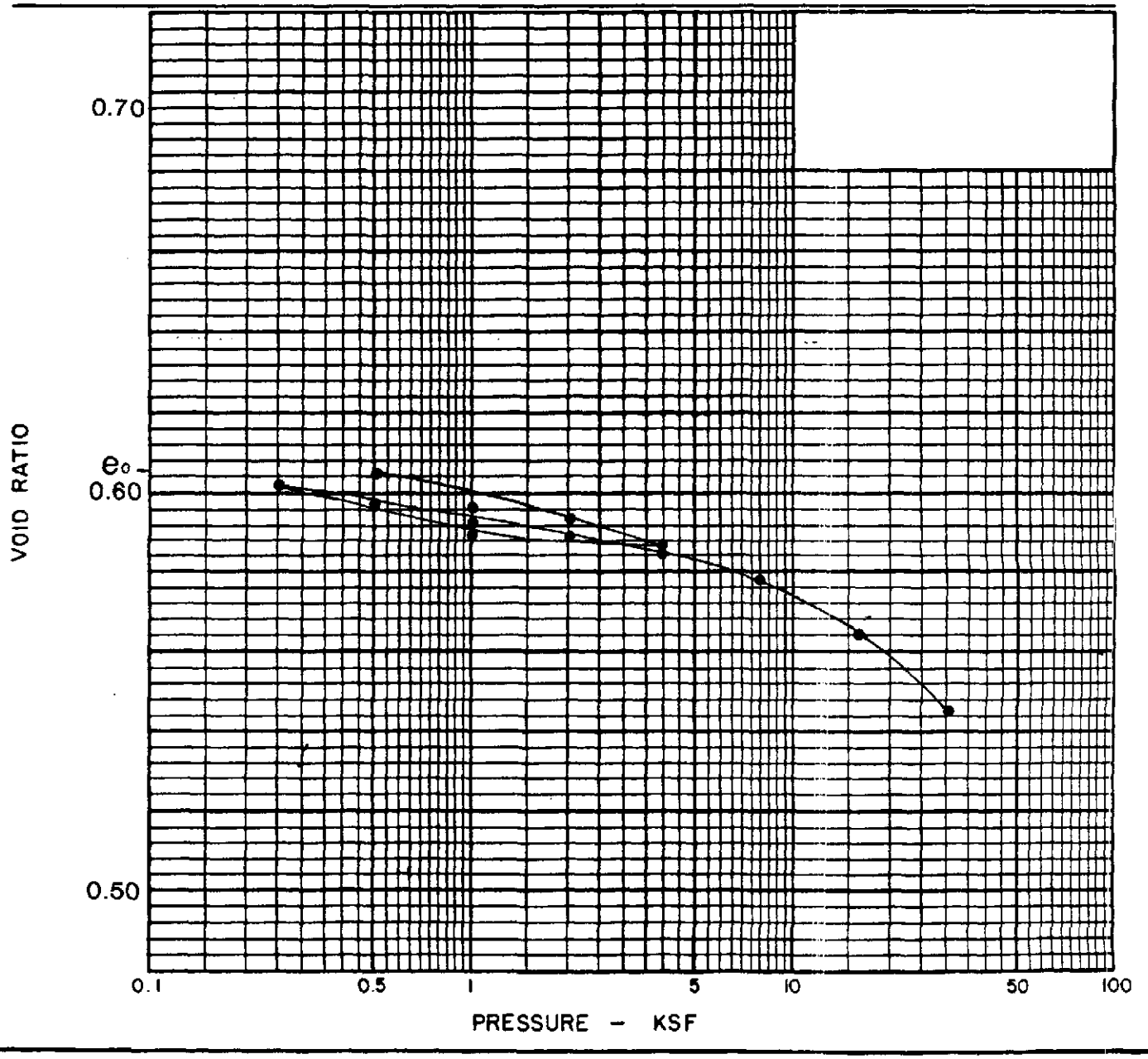
BORING NO. _____ SAMPLE NO. _____ DEPTH _____ ELEV. _____

DESCRIPTION Hubbardston Sand

INITIAL SAMPLE HEIGHT	.755 IN.	SAMPLE AREA	4.893 SQ. IN.	SPECIFIC GRAVITY	2.75
INITIAL MOISTURE CONTENT	6.64 %	INITIAL BULK DENSITY	113.80 PCF	INITIAL DRY DENSITY	106.71 PCF
INITIAL VOID RATIO	.606	INITIAL SATURATION	30.2 %	FINAL SATURATION	100.0 %

ATTERBERG LIMITS: L_w _____ % I_w _____ % P_w NP %

REMARKS: _____



Scale AS SHOWN
Date 9/6/90
Job No. 893-6255

Golder Associates

Drawn LAS
Checked RJI
Reviewed PCR

Baker Tests for Soil Fertility

PENNSTATE

College of Agriculture

Cooperative Extension Service
Agronomy Extension
Department of Agronomy

The Pennsylvania State University
University Park, PA

August 23, 1990

AUG 29 1990

Mr. Bob Illes
Golder Assoc. Inc.
20000 Horizon Way
Suite 500
Mt. Laurel, NS 08054

Dear Mr. Illes:

Enclosed are diagnostic soil test results for the five (5) samples you recently submitted. By now you should have received the Merkle Lab soil test results and fertilizer and limestone recommendations for these samples.

Also enclosed is a mimeographed table which lists the ranges of values for the available amount (lbs/acre) and availability (p value) for the individual elements. These ranges correspond to the low, normal, and high ranges illustrated as a series of stars on the printout of results.

These diagnostic soil test results do not indicate any present potential problems of deficiencies or toxicities to plants for the available levels of heavy metals and trace elements determined.

If you have questions about these results and interpretations, please let me or your County Extension Agent know.

Sincerely,

Raymond F. Shipp
Assoc. Prof. of Agronomy

Enclosures: Diagnostic Soil Test Results, Sample P1888 through P1892
Table of Soil Test Ranges

cc: D. Baker
W. Doty

Alder Assoc. Inc.
Attn: Bob Illes
20000 Horizon Way Suite 500
Mt. Laurel, N.J. 08054

The Pennsylvania State University
Soil and Environmental Chem. Lab.
104 Research Unit A
University Park, PA 16802

INTERPRETED DATA FOR BAKER SOIL TEST

Identification	Date	Lab. No.	County	Soil	Lime (t/ac)	Soil pH	Baker Test pH	CEC (meq/100 g)
BrF1882	08/22/90	6776	68	340	1.00	6.20	6.58	5.60

	Test Level	Low	Normal	High
Prev I	140.00		**********	
Phosphorus				
Lb/A				
Potassium				
Exchangeable	78.00	*		
Lb/A				
Exchangeable	1.79	**********		
% of CEC				
pK	3.75	**********		
Magnesium				
Exchangeable	168.00	**********		
Lb/A				
Exchangeable	12.50	**********		
% of CEC				
pMg	3.24	**********		
Calcium				
Exchangeable	920.00	*		
Lb/A				
Exchangeable	41.07	**********		
% of CEC				
pCa	2.61	**********		
Cation Balance				
(Ca+Mg)/K	5.32	**********		
Mg/K	2.13	**********		
Ca/Mg	6.63	**********		
Manganese				
Available	6.80	**********		
Lb/A				
pMn	8.79	**********		
Iron				
Available	156.00	**********	**********	**********
Lb/A				
pFe	19.76	**********		
Copper				
Available	1.40	**********		
Lb/A				
pCu	15.15	**********		
Total Cu	0.00			
Lb/A				

older Assoc. Inc.

The Pennsylvania State University
Soil and Environmental Chem. Lab.
104 Research Unit A
University Park, PA 16802

INTERPRETED DATA FOR BAKER SOIL TEST

Identification	Date	Lab. No.	County	Soil	Lime (t/ac)	Soil pH	Baker Test pH	CEC (meq/100 g)
B:P1889	08/22/90	6777	68	340	1.00	6.20	6.84	5.60

	Test Level	Low	Normal	High
Bray 1 Phosphorus	140.00			**********
Lb/A				
Potassium				
Exchangeable	78.00	*		
Lb/A				
Exchangeable % of CEC	1.79	**********		
pK	3.76	**********		
Magnesium				
Exchangeable	120.00	**********		
Lb/A				
Exchangeable % of CEC	8.93	**********		
pMg	3.29	**********		
Calcium				
Exchangeable	1000.00	*		
Lb/A				
Exchangeable % of CEC	44.64	**********		
pCa	2.58	**********		
Cation Balance				
(Ca+Mg)/K	5.39	**********		
Mg/K	2.11	**********		
Ca/Mg	0.71	**********		
Manganese				
Available	4.20	**		
Lb/A				
pMn	9.00	*		
Iron				
Available	140.00	**********		
Lb/A				
pFe	19.79	**********		
Copper				
Available	1.40	**********		
Lb/A				
pCu	15.14	**********		
Total Cu	0.00			
Lb/A				

	Low	Normal	High

[illegible]ber Assoc. Inc.

The Pennsylvania State University
Soil and Environmental Chem. Lab.
104 Research Unit A
University Park, PA 16802

INTERPRETED DATA FOR BAKER SOIL TEST

Identification	Date	Lab. No.	County	Soil	Lime (t/ac)	Soil pH	Baker Test pH	CEC (meq/100 g)
B:P1896	08/22/90	6778	69	340	1.00	5.80	6.70	5.80

	Test Level	Low	Normal	High
Bray 1 Phosphorus Lb/A	198.00			
Potassium				
Exchangeable Lb/A	70.20	*		
Exchangeable % of CEC	1.55	**********		
pK	3.69	**********		
Magnesium				
Exchangeable Lb/A	120.00	*********		
Exchangeable % of CEC	8.62	**********		
pMg	3.27	**********		
Calcium				
Exchangeable Lb/A	1320.00	**		
Exchangeable % of CEC	56.90	**********		
pCa	2.55	**********		
Cation Balance				
(Ca+Mg)/K	5.46	**********		
Mg/K	2.06	**********		
Ca/Mg	6.72	**********		
Manganese				
Available Lb/A	4.80	***		
pMn	8.94	*		
Iron				
Available Lb/A	154.00	**********	**********	
pFe	19.75	**********		
Copper				
Available Lb/A	2.40	**********		
pCu	14.91	**********		
Total Cu Lb/A	0.00			

Ulger Assoc. Inc.

The Pennsylvania State University
Soil and Environmental Chem. Lab.
104 Research Unit A
University Park, PA 16802

INTERPRETED DATA FOR BAKER SOIL TEST

Identification	Date	Lab. No.	County	Soil	Lime (t/ac)	Soil pH	Baker Test pH	CEC (meq/100 g)
B:P1891	08/22/90	6779	68	340	1.00	5.86	6.31	6.00

	Test Level	Low	Normal	High
Bray 1 Phosphorus Lb/A	78.00	**********		
Potassium				
Exchangeable Lb/A	156.00	**********		
Exchangeable % of CEC	3.33	**********		
pK	3.69	**********		
Magnesium				
Exchangeable Lb/A	144.00	**********		
Exchangeable % of CEC	16.00	**********		
pMg	3.24	**********		
Calcium				
Exchangeable Lb/A	1606.00	**********		
Exchangeable % of CEC	41.67	**********		
pCa	2.58	**********		
Cation Balance				
(Ca+Mg)/K	5.06	**********		
Mg/K	2.07	**********		
Ca/Mg	0.66	**********		
Manganese				
Available Lb/A	10.60	**********		
pMn	8.38	**********		
Iron				
Available Lb/A	216.00	**********	**********	**********
pFe	19.38	**********	**********	
Copper				
Available Lb/A	1.20	**********		
pCu	15.00	**********		
Total Cu Lb/A	0.00			
		Low	Normal	High

Elder Assoc. Inc.

The Pennsylvania State University
Soil and Environmental Chem. Lab.
104 Research Unit A
University Park, PA 16802

INTERPRETED DATA FOR BAKER SOIL TEST

Identification	Date	Lab. No.	County	Soil	Lime (t/ac)	Soil pH	Baker Test pH	CEC (meq/100 g)
B:F1892	08/22/90	6781	63	340	1.00	5.70	6.25	5.20

	Test Level	Low	Normal	High
Bray 1	161.00		**********	**********
Phosphorus				
Lb/A				
Potassium				
Exchangeable	93.60	*****		
Lb/A				
Exchangeable	2.31	**********		
% of CEC				
pK	3.72	**********		
Magnesium				
Exchangeable	120.00	*********		
Lb/A				
Exchangeable	9.62	**********		
% of CEC				
pMg	3.27	**********		
Calcium				
Exchangeable	800.00	*		
Lb/A				
Exchangeable	38.46	*******		
% of CEC				
pCa	2.57	**********		
Cation Balance				
(Ca+Mg)/K	5.00	**********		
Mg/K	2.69	**********		
Ca/Mg	0.69	**********		
Manganese				
Available	7.00	****		
Lb/A				
pMn	8.64	********		
Iron				
Available	142.00	**********	**********	
Lb/A				
pFe	19.64	**********		
Copper				
Available	1.60	**********		
Lb/A				
pCu	14.96	**********		
Total Cu	0.00			
Lb/A				

PENNSTATE

OFFICE OF THE DEAN
COLLEGE OF AGRICULTURE

Date: July 30, 1990

From: James L. Starling
Associate Dean for Administration

Al J. Turgeon
Head, Department of Agronomy

To: Users of Penn States' Sewage Sludge and Sludge-Amended Soils Testing and Educational Service Program

You may have recently received information from Dr. Dale E. Baker announcing his establishment of a private firm called Land Management Decisions, Inc. that will be doing analyses of sludges and soils. While Dr. Baker is now offering these services as a private venture, you should be aware that the Penn State College of Agriculture will continue to provide sludge and soil analyses as part of its on-going educational service program. By continuing to send samples to Penn State, you will receive the same service that has been offered in recent years. Sludge and soil samples intended for the Penn State program should now be addressed to:

Merkle Laboratory
Penn State University
University Park, PA 16802

If you have further questions or concerns, please feel free to call:
Dr. R. F. Shipp, Associate Professor, Agronomy, at 814/863-1015 or
Dr. A. M. Wolf, Manager, Merkle Laboratory, at 814/863-0841.

JLS/grm

08/14/90	6776	047165	OUT OF STATE	00	KPEN 2	UNSPECIFIED
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

THE PENNSYLVANIA STATE UNIVERSITY
COLLEGE OF AGRICULTURE
MERKLE LABORATORY - SOIL TESTING
UNIVERSITY PARK, PA 16802
(814 863-0841)

SOIL TEST REPORT FOR:

BOB ILLES
20000 HORIZON WAY
MT LAUREL NJ 08054

COPY SENT TO:

RAY SHIPP
140 AG ADMIN
00000

SOIL NUTRIENT LEVELS:

				LOW	OPTIMUM	HIGH	EXCESSIVE
Soil pH		6.2		XXXXXXXXXXXX			
Phosphate	(P_2O_5)	322	lb/A	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX			
Potash	(K_2O)	94	lb/A	XXXXXXXXXXXXX			
Magnesium	(MgO)	276	lb/A	XXXXXXXXXXXXXXXXXXXXXXX			

RECOMMENDATIONS FOR: *NOT SPECIFIED* (For other crops see ST 2 column: 7)

See Back For Comments
1.2
3.4

YIELD GOAL N/A

LIMESTONE: *2000* lb/A Calcium Carbonate Equivalent

PLANT NUTRIENT NEEDS:	NITROGEN (N)	PHOSPHATE (P_2O_5)	POTASH (K_2O)	MAGNESIUM (MgO)
	N/A lb/A	*N/A* lb/A	*N/A* lb/A	*N/A* lb/A

MESSAGES:

* NO CROP WAS INDICATED - THEREFORE NO RECOMMENDATION IS GIVEN
* FOR ALFALFA AND BARLEY, THE PH GOAL IS 7.0. FOR ALL OTHER CROPS, THE LIMESTONE RECOMMENDATION, IF ANY, IS TO BRING THE PH TO 6.5. TO ESTIMATE THE LIME REQUIREMENT FOR PH 7.0 FOR THESE CROPS, MULTIPLY THE EXCHANGEABLE ACIDITY BY 1000.
* IF MANURE WILL BE APPLIED, SEE ST-10 "USE OF MANURE" 9

LABORATORY RESULTS:

6.2	140	2.5	0.10	0.7	2.3	5.6	1.7	12.8	40.1
SOIL pH	P lb/A	ACIDITY	K	Mg	Ca	CEC	K	Mg	Ca
		EXCHANGEABLE CATIONS (meq/100 g)					% SATURATION		

OTHER TESTS:

SOIL 1 AGRONOMIC

08/14/90	6778	047161	OUT OF STATE	00	BILLER	UNSPECIFIED
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

THE PENNSYLVANIA STATE UNIVERSITY
COLLEGE OF AGRICULTURE
MERKLE LABORATORY - SOIL TESTING
UNIVERSITY PARK, PA 16802
(814 863-0841)

SOIL TEST REPORT FOR:

BOB ILLES
20000 HORIZON WAY
MT LAUREL NJ 08054

COPY SENT TO:

RAY SHIPP
140 AG ADMIN
00000

SOIL NUTRIENT LEVELS:

		Value		LOW / OPTIMUM / HIGH / EXCESSIVE
Soil pH		5.8		XXXXXXXX
Phosphate	(P_2O_5)	455	lb/A	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Potash	(K_2O)	84	lb/A	XXXXXXXXXXX
Magnesium	(MgO)	195	lb/A	XXXXXXXXXXXXXXXXXXX

RECOMMENDATIONS FOR: *NOT SPECIFIED* (For other crops see ST 2 column: 7)

See Back For Comments

YIELD GOAL N/A

LIMESTONE: *2000* lb/A Calcium Carbonate Equivalent 1,2 3,4

PLANT NUTRIENT NEEDS:

NITROGEN (N)	PHOSPHATE (P_2O_5)	POTASH (K_2O)	MAGNESIUM (MgO)
N/A lb/A	*N/A* lb/A	*N/A* lb/A	*N/A* lb/A

MESSAGES:

* NO CROP WAS INDICATED - THEREFORE NO RECOMMENDATION IS GIVEN
* EXCESSIVE PHOSPHATE AND/OR POTASH LEVEL. 10
* FOR ALFALFA AND BARLEY, THE PH GOAL IS 7.0. FOR ALL OTHER CROPS, THE LIMESTONE RECOMMENDATION, IF ANY, IS TO BRING THE PH TO 6.5. TO ESTIMATE THE LIME REQUIREMENT FOR PH 7.0 FOR THESE CROPS, MULTIPLY THE EXCHANGEABLE ACIDITY BY 1000.
* IF MANURE WILL BE APPLIED, SEE ST-10 "USE OF MANURE" 9

LABORATORY RESULTS:

SOIL pH	P lb/A	ACIDITY	K	Mg	Ca	CEC	K	Mg	Ca
		EXCHANGEABLE CATIONS (meq/100 g)					% SATURATION		
5.8	198	2.0	0.09	0.5	3.3	5.8	1.5	8.7	56.0

OTHER TESTS:

SOIL 01 AGRONOMIC

08/14/90	6781	047163	OUT OF STATE	00	KPSCR	UNSPECIFIED
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

THE PENNSYLVANIA STATE UNIVERSITY
COLLEGE OF AGRICULTURE
MERKLE LABORATORY - SOIL TESTING
UNIVERSITY PARK, PA 16802
(814 863-0841)

SOIL TEST REPORT FOR:

BOB ILLES
20000 HORIZON WAY
MT LAUREL NJ 08054

COPY SENT TO:

RAY SHIPP
140 AG ADMIN
00000

SOIL NUTRIENT LEVELS:

				LOW	OPTIMUM	HIGH	EXCESSIVE
Soil pH		5.7		XXXXXX			
Phosphate	(P_2O_5)	371	lb/A	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX			
Potash	(K_2O)	112	lb/A	XXXXXXXXXXXXXXXXX			
Magnesium	(MgO)	207	lb/A	XXXXXXXXXXXXXXXXXXXX			

RECOMMENDATIONS FOR: *NOT SPECIFIED* (For other crops see ST 2 column: 8)

See Back For Comments

YIELD GOAL N/A

LIMESTONE: *2000* lb/A Calcium Carbonate Equivalent — 1,2 3,4

*
*

PLANT NUTRIENT NEEDS:	NITROGEN (N)	PHOSPHATE (P_2O_5)	POTASH (K_2O)	MAGNESIUM (MgO)
	N/A lb/A	*N/A* lb/A	*N/A* lb/A	*N/A* lb/A

MESSAGES:

* NO CROP WAS INDICATED - THEREFORE NO RECOMMENDATION IS GIVEN
* EXCESSIVE PHOSPHATE AND/OR POTASH LEVEL. 10
* FOR ALFALFA AND BARLEY, THE PH GOAL IS 7.0. FOR ALL OTHER CROPS, THE LIMESTONE RECOMMENDATION, IF ANY, IS TO BRING THE PH TO 6.5. TO ESTIMATE THE LIME REQUIREMENT FOR PH 7.0 FOR THESE CROPS, MULTIPLY THE EXCHANGEABLE ACIDITY BY 1000.
* IF MANURE WILL BE APPLIED, SEE ST-10 "USE OF MANURE" 9
* RE-TEST NEXT YEAR

LABORATORY RESULTS:

SOIL pH	P lb/A	ACIDITY	K	Mg	Ca	CEC	K	Mg	Ca
5.7	161	2.5	0.12	0.5	2.0	5.2	2.3	10.3	38.4
		EXCHANGEABLE CATIONS (meq/100 g)					% SATURATION		

OTHER TESTS:

SOIL 01 AGRONOMIC

INTERPRETING SOIL TESTS FOR AGRONOMIC CROPS

ST 4
3/85

A step-by-step explanation of the test report from the Soil and Forage Testing Laboratory.

DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL
10/03/84	2076	065956	YORK	02	22 E	CHESTER

THE PENNSYLVANIA STATE UNIVERSITY
COLLEGE OF AGRICULTURE
MERKLE LABORATORY - SOIL & FORAGE TESTING
UNIVERSITY PARK, PA 16802

SOIL TEST REPORT FOR:

P. A. PENN
R D 1
ANYTOWN, PA 10000

COPY SENT TO:

ACME FERTILIZER CO.
MAIN STREET
ANYTOWN, PA 10000

SOIL NUTRIENT LEVELS:

				LOW / OPTIMUM / HIGH / EXCESSIVE
Soil pH		6.1		XXXXXXXXXXXXX
Phosphate	(P_2O_5)	114	lb/A	XXXXXXXXXXXX
Potash	(K_2O)	356	lb/A	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
Magnesium	(MgO)	276	lb/A	XXXXXXXXXXXXXXXXX

RECOMMENDATIONS FOR: *PLANTING CORN FOR GRAIN* (For other crops see ST 2 column 3)

See Back For Comments

YIELD GOAL 150.0 BUSHELS (PER ACRE) 1, 2

LIMESTONE: 2400 lb/A Calcium Carbonate Equivalent 3, 4

PLANT NUTRIENT NEEDS:

NITROGEN (N)	PHOSPHATE (P_2O_5)	POTASH (K_2O)	MAGNESIUM (MgO)
160 lb/A	80 lb/A	0 lb/A	0 lb/A

5, 11

MESSAGES:

- USE A STARTER FERTILIZER 6, 7
- LIMESTONE RECOMMENDATION, IF ANY, IS TO BRING THE SOIL PH TO 6.0 - 6.5. MULTIPLY THE EXCHANGABLE ACIDITY BY 1000 TO ESTIMATE THE LIME REQUIREMENT FOR PH 6.5 - 7.0.
- IF MANURE WILL BE APPLIED, SEE ST-10 "USE OF MANURE"

LABORATORY RESULTS:

SOIL pH	P lb/A	ACIDITY	K	Mg	Ca	CEC	K	Mg	Ca
		EXCHANGEABLE CATIONS (meq/100 g)					% SATURATION		
6.1	50	3.9	0.38	0.7	5.0	10.0	3.8	7.1	50.0

OTHER TESTS:

The Pennsylvania State University
College of Agriculture

RECOMMENDATIONS:
The recommendation on the soil test report is made for a specific crop and yield level. Detailed information for changing the recommendation to a different crop and or yield level is given in ST 2 "Fertilizer Recommendation Table." The soil test report indicates which column on ST 2 should be used to change the crop.

Limestone Recommendation Limestone is applied to neutralize the acidity in the soil and thus raise the soil pH into the optimum range for crop growth. The limestone recommendation is based on the amount of exchangeable acidity measured by the SMP lime requirement soil test and the optimum soil pH level for the crop. For most agronomic crops the optimum pH is 6.5 except for alfalfa, barley, and soybeans which require a pH level near to 7.0.

For a desired pH of 7.0 the lime requirement is calculated as follows:

Lime Requirement = Exchangeable Acidity X 1000

For a desired pH of 6.5 the lime requirement is calculated as follows:

If the exchangeable acidity is greater than 4.0 then
Lime Requirement = Exchangeable Acidity x 840

If the exchangeable acidity is less than 4.0 and the soil pH is still less than 6.5 then:

Lime Requirement = 2000 lbs./A

Otherwise no lime is recommended.

This recommendation is based on a liming material that is 100% calcium carbonate equivalent (CCE) in neutralizing power and on liming an acre furrow slice seven inches deep. If a liming material is used that is not near to 100% CCE (90 - 110% CCE) then the rate should be adjusted for lime quality. The "Liming Materials Conversion Table" gives the details for making this simple but important adjustment. If the limestone is going to be mixed with a larger volume of soil ie. If the plow depth is greater than 7 inches then the recommendation is adjusted as follows:

Plow Depth	Adjusted Limestone Requirement
Less than 9 inches	No adjustment
9 to 11 inches	Basic requirement X 1.5
More than 12 inches	Basic requirement X 1.8

Magnesium Recommendation If the magnesium level of the soil is below the optimum level for crop production then magnesium will be recommended to raise the level to optimum. The recommended amount is simply the difference between the minimum optimum level (see above) and the actual soil test level. Agricultural limestone is generally the most economical and convenient source of magnesium for agronomic crops. In addition to the actual amount of magnesium recommended the magnesium recommendation is also given as the minimum percentage of MgO in the recommended amount of limestone that is required to meet the magnesium needs.

Nitrogen Recommendation There is currently no acceptable soil test for nitrogen for Pennsylvania conditions. Thus all nitrogen recommendations are based on average estimates of crop requirements for nitrogen as determined by extensive crop response research under Pennsylvania conditions. The nitrogen recommendations also take a previous legume crop into consideration. The nitrogen supplied by manure should also be considered in determining the final nitrogen recommendation. See ST 10 "Use of Manure" for details.

Phosphorus Recommendation The phosphorus recommendation is based on gradually building the soil level into the optimum range and then maintaining it there. The optimum range is given above. The crop removal generally varies between 50 and 100 pounds of P_2O_5 per acre depending on the crop and the yield level. It is known that several pounds of P_2O_5 are required to change the soil test by one pound therefore this recommendation assumes that this amount will be applied for several years in order to gradually build the soil level of phosphorus into the optimum range.

The recommendation is calculated as follows:

Minimum Optimum P_2O_5	+	Crop Removal P_2O_5	–	Soil Test P_2O_5	=	Needed P_2O_5

Using the results from the example this calculation would be:

140	+	55	–	114	=	81 lbs. A P_2O_5

Potassium Recommendation The potassium recommendation is also based on gradually building the soil level into the optimum range and then maintaining it there. The formula for calculating the potash needed is the same as for phosphate:

Minimum Optimum K_2O	+	Crop Removal K_2O	–	Soil Test K_2O	=	Needed K_2O

Using the results from the example this example would be:

190	+	40	–	336	=	–126 lbs. A Excess K_2O

The optimum level is given above and the crop removal generally varies between 30 and 100 pounds per acre for grain crops and between 125 and 350 pounds per acre for forage crops. Although potassium will build up the soil faster than will phosphorus, this recommendation still assumes that several years of applying the recommended amount will be required to build the soil into the optimum range.

An important part of the recommendations are the messages and comments that go with the recommendations for lime and plant nutrients. Immediately under the amounts of nutrients needed are several messages specific to the actual results and recommendations. Also along the right side of the report are reference numbers which refer to important general comments about the results and recommendations which are found on the back of the report. These comments and messages on the report and the material enclosed with the report are all part of the recommendation.

LABORATORY DATA:
The actual laboratory data from the analysis of your soil sample is included at the bottom of the report along with the results of any optional tests performed. It is generally not necessary to use this data once the interpretation and recommendation are determined.

Calculation of Available Manure Nutrients:

Available N = Total N × N availability factor (Table 2).

Based on the time until incorporation (4 days in this example), the N availability factor = 0.3.

Available N = 24 tons × 10 lb. N per ton × 0.3 = 72 lb. N per acre

- OR - 240 lb. total N* per acre × 0.3 = 72 lb. N per acre.

Residual N = Total N × Residual N availability factor (Table 3)

Based on previous manure applications (Frequent in this example), Residual N availability factor = .15

Residual N = 24 tons × 10 lb. N per ton × 0.15 = 36 lb. N per acre

- OR - 240 lb. total N* per acre × 0.15 = 36 lb. N per acre

Available P_2O_5 and K_2O = Total P_2O_5 and K_2O.

Available P_2O_5 = 24 tons × 3 lb. P_2O_5 per ton = 72 lb. P_2O_5* per acre,

Available K_2O = 24 tons × 5 lb. K_2O per ton = 120 lb. K_2O* per acre.

* If manure information was provided on the soil test information sheet the total N and total available P_2O_5 and K_2O can be taken directly from the soil test report.

Calculation of Net fertilizer requirement:

		N	P_2O_5	K_2O
Soil test recommendation		160	150	100
(-) Nutrients in manure	(-)	72	72	120
(-) Residual N from previous manure applications)	(-)	36		
Net fertilizer nutrients required		52	78	(-20)**

(**NOTE: 20 lb. K_2O in excess of crop requirement were applied in the manure)

Table 1. Average total nutrient content of manure

Animal type	Manure % dry matter	lb. per ton N	P_2O_5	K_2O
Dairy cattle	13	10	4	8
Veal	2	8	2	11
Beef cattle	12	11	7	10
Swine	9	14	11	11
Sheep	25	23	8	20
Horse	20	12	5	9
Poultry:				
fresh	25	30	20	10
moist	50	40	40	20
crumbly	70	60	55	30
dry	85	100	70	40

IMPORTANT NOTE: When possible, have manure analyzed

Table 2. Manure nitrogen availability based on time of application and incorporation.

Time of application and Incorporation	N availability factor Poultry manure	Other manure
Applied this year		
incorporation within 2 days	0.75	0.50
incorporation within 3-4 days	0.45	0.35
incorporation within 5-6 days	0.30	0.30
incorporation after 7 days or no incorporation	0.15	0.20
Applied previous fall regardless of incorporation	0.15	0.20

Table 3. Residual nitrogen availability from previous manure applications.

Incorporation	Residual N availability factor Poultry manure	Other manure
Rarely received manure in past	0	0
Frequently received manure (5-6 out of 10 years)	7	15
Continuously received manure (9-10 out of 10 years)	12	25

Prepared by: Douglas Beegle and Phillip Durst, Extension Agronomists.

LIMING MATERIAL CONVERSION TABLE FOR FIELD CROPS

The limestone recommendation on your soil test report is based on the use of a liming material equivalent in neutralizing power to 100% calcium carbonate limestone. The recommendations are in pounds of calcium carbonate equivalent (CCE) per acre. The use of any liming material that is not equivalent in neutralizing power to pure calcium carbonate limestone (100% CCE) must be adjusted so that you actually apply enough liming material to neutralize the acidity in your soil. All agricultural liming materials sold in Pennsylvania are required by law to be labeled with their calcium carbonate equivalent (CCE). Using the CCE of your liming material, the amount required to supply the recommended amount of neutralizing power (CCE) for your soil may be calculated as shown below or read directly from the table.

It is also very important that a liming material be ground fine enough to be effective. Pennsylvania law requires that agricultural limestone meet the following standards:

95% through a 20 mesh screen
60% through a 60 mesh screen
50% through a 100 mesh screen

Calculation of Actual Lime Requirement:

$$\text{Actual Liming Material Required} = \frac{\text{Soil Test Limestone Recommendation}}{\text{CCE of liming material to be used}} \times 100$$

Example:
Soil Test Recommendation:
***Limestone - Apply 4,000 lbs. of calcium carbonate equivalent per acre.

Liming Material Label:
Calcium Carbonate Equivalent (CCE) = 80%

Actual Liming Material Required:
$\frac{4000}{80} \times 100 = 5{,}000$ lbs. liming material per acre.

The above calculations for adjusting your limestone recommendation for the CCE of your liming material assumes that you are using a material that at least meets the minimum fineness standard.

A high quality, finely ground liming material will react more quickly with the soil and is thus advantageous when more rapid neutralization is required. However, there may be little advantage to paying a premium for liming materials that are ground much finer than the minimum standards.

Directions for using the conversion table:
Find your test limestone recommendation in the left hand column and then read across the table on that line until you come to the column headed by the % CCE nearest to that of your liming material. The number at that point is the pounds of liming material required to meet the limestone recommendation on your soil test.

Because there is generally little advantage to applying more than 8,000 pounds of CCE per acre in any one application to agricultural land, this table is divided into three sections suggesting how the total liming material required can be split for more efficient use. Separate the applications by 6 months time or at least by tillage operations. (See the right hand column).

Pounds per acre of Calcium Carbonate Equivalent recommended on your soil test.	Percent Calcium Carbonate Equivalent (%CCE) of Your Liming Material								Divide Total into the Following Number Applications
	70	75	80	85	90	95	100	105	
1000	1400	1300	1200	1200	1100	1100	1000	1000	
2000	2900	2700	2500	2400	2200	2100	2000	1900	
3000	4300	4000	3700	3500	3300	3200	3000	2900	
4000	5700	5300	5000	4700	4400	4200	4000	3800	1
5000	7100	6700	6200	5900	5600	5300	5000	4800	
6000	8600	8000	7500	7100	6700	6300	6000	5700	
7000	10000	9300	8700	8200	7800	7400	7000	6700	
8000	11400	10700	10000	9400	8900	8400	8000	7600	
9000	12900	12000	11200	10600	10000	9500	9000	8600	
10000	14300	13300	12500	11800	11100	10500	10000	9500	
11000	15700	14700	13700	12900	12200	11600	11000	10500	
12000	17100	16000	15000	14100	13300	12600	12000	11400	
13000	18600	17300	16200	15300	14400	13200	13000	12400	2
14000	20000	18700	17500	16500	15600	14700	14000	13300	
15000	21400	20000	18700	17600	16700	15800	15000	14300	
16000	22900	21300	20000	18800	17800	16800	16000	15200	
17000	24300	22700	21200	20000	18900	17900	17000	16200	
18000	25700	24000	22500	21200	20000	18900	18000	17100	3
19000	27100	25300	23700	22400	21100	20000	19000	18100	
20000	28600	26700	25000	23500	22200	21100	20000	19000	

To convert to 1000 sq. ft. rate, divide the recommended value in the table by 43.5.

Prepared By: Douglas Beegle, Extension Agronomist.

APPENDIX C

Geosynthetics Laboratory Data

AUGUST 1990

SUMMARY OF GEOMEMBRANE
CONFORMANCE TEST RESULTS

MATERIAL TYPE
GOLDER ASSOCIATES, INC.
893-6255.1
MASSACHUSSETTS

907-1086

ROLL DESIGNATION	GUNDLE 2	NSC 3	SLT 6	–	–	–	–	–	–	–
THICKNESS (mils) ASTM D 374	53.1	40.7	75.3	–	–	–	–	–	–	–
SPECIFIC GRAVITY ASTM D 1505	–	–	–	–	–	–	–	–	–	–
STRENGTH AT YIELD (ppi)	131.1	107.9	217.3	–	–	–	–	–	–	–
MD/TD (1) ASTM D 638	132.7	109.0	210.7	–	–	–	–	–	–	–
STRENGTH AT BREAK (ppi)	218.1	175.8	406.4	–	–	–	–	–	–	–
MD/TD (1) ASTM D 638	216.4	162.9	405.3	–	–	–	–	–	–	–
ELONGATION AT YIELD (%)	12.8	12.3	11.1	–	–	–	–	–	–	–
MD/TD (1) ASTM D 638	11.6	12.1	11.4	–	–	–	–	–	–	–
ELONGATION AT BREAK (%)	796	826	848	–	–	–	–	–	–	–
MD/TD (1) ASTM D 638	782	834	890	–	–	–	–	–	–	–
CARBON BLACK CONTENT (%) ASTM D 1603	–	–	–	–	–	–	–	–	–	–
PUNCTURE RESISTANCE (lbs.) FTMS 101C	73.5	56.0	110.0	–	–	–	–	–	–	–

(1) MD/TD corresponds to Machine Direction / Transverse Direction.

AUGUST 1990 907-1086

GEOMEMBRANE TEST RESULTS

PROJECT NUMBER: 907-1086
PROJECT NAME: GAI/893-6255.1/MASS
ROLL DESIGNATION: 2

	THICKNESS (mils)		SPECIFIC GRAVITY		CARBON BLACK CONTENT (%)		PUNCTURE RESISTANCE (lbs.)
1.	54.5	1.	-	1.	-	1.	75.4
2.	53.0	2.	-	2.	-	2.	74.1
3.	50.9	3.	-			3.	73.5
4.	51.0					4.	71.0
5.	55.3					5.	73.5
6.	54.7						
7.	52.0						
8.	51.7						
9.	53.6						
10.	54.6						
AVG	53.1		0.000		0.00		73.5

	YIELD STRENGTH (lb/in. width)		ELONGATION AT YIELD (%)		BREAK STRENGTH (lb/in. width)		ELONGATION AT BREAK (%)	
	MD	TD	MD	TD	MD	TD	MD	TD
1.	131.8	129.8	12.4	11.3	217.8	210.4	790	790
2.	131.0	129.7	13.6	12.2	206.4	192.4	760	760
3.	130.2	132.1	13.4	12.0	230.4	222.4	810	770
4.	128.3	135.5	13.2	11.2	221.4	230.0	820	800
5.	134.2	136.6	11.4	11.7	214.6	226.8	800	790
AVG	131.1	132.7	12.8	11.6	218.1	216.4	796	782

AUGUST 1990 907-1086

GEOMEMBRANE TEST RESULTS

PROJECT NUMBER: 907-1086
PROJECT NAME: GAI/893-6255.1/MASS
ROLL DESIGNATION: 3

	THICKNESS (mils)		SPECIFIC GRAVITY		CARBON BLACK CONTENT (%)		PUNCTURE RESISTANCE (lbs.)
1.	41.3	1.	-	1.	-	1	56.0
2.	41.2	2.	-	2.	-	2	56.3
3.	40.0	3.	-			3	55.0
4.	39.7					4	55.8
5.	40.6					5	57.0
6.	40.3						
7.	40.8						
8.	40.6						
9.	41.0						
10.	41.3						
AVG	40.7		0.000		0.00		56.0

	YIELD STRENGTH (lb/in. width)		ELONGATION AT YIELD (%)		BREAK STRENGTH (lb/in. width)		ELONGATION AT BREAK (%)	
	MD	TD	MD	TD	MD	TD	MD	TD
1.	107.7	108.0	11.5	12.4	181.6	162.6	850	830
2.	108.0	110.9	11.4	11.9	189.6	167.2	860	820
3.	107.7	105.4	11.8	12.9	164.6	165.2	830	850
4.	107.4	109.5	13.1	11.6	175.0	166.6	810	850
5.	108.4	111.2	13.5	11.7	168.0	153.0	780	820
AVG	107.9	109.0	12.3	12.1	175.8	162.9	826	834

AUGUST 1990 907-1086

GEOMEMBRANE TEST RESULTS

PROJECT NUMBER: 907-1086
PROJECT NAME: GAI/893-6255.1/MASS
ROLL DESIGNATION: 6

	THICKNESS (mils)	SPECIFIC GRAVITY	CARBON BLACK CONTENT (%)	PUNCTURE RESISTANCE (lbs.)
1.	76.6	–	–	107.3
2.	76.1	–	–	107.6
3.	73.6	–		107.8
4.	78.5			110.5
5.	73.9			117.0
6.	70.8			
7.	74.5			
8.	76.1			
9.	77.5			
10.	74.9			
AVG	75.3	0.000	0.00	110.0

	YIELD STRENGTH (lb/in. width)		ELONGATION AT YIELD (%)		BREAK STRENGTH (lb/in. width)		ELONGATION AT BREAK (%)	
	MD	TD	MD	TD	MD	TD	MD	TD
1.	216.9	207.8	10.5	11.1	428.4	385.0	880	860
2.	226.7	219.8	11.4	11.0	451.6	447.2	900	1040
3.	213.3	201.8	11.5	11.1	414.8	385.6	870	860
4.	216.0	212.6	11.2	11.8	376.4	378.0	790	790
5.	213.8	211.6	11.0	11.8	361.0	430.8	800	900
AVG	217.3	210.7	11.1	11.4	406.4	405.3	848	890

AUGUST 1990

907-1086

SUMMARY OF GEOTEXTILE
CONFORMANCE TEST RESULTS

GOLDER ASSOCIATES, INC.
893-6255.1
MASSACHUSSETTS

ROLL DESIGNATION	AMOCO 4	HORCHST CELANESE 1114	POLYFELT 5	–	–	–	–	–	–	–
THICKNESS (mils) ASTM D 1777	–	–	–	–	–	–	–	–	–	–
MASS/UNIT AREA (oz/sq yd) ASTM D 3776	4.0	5.0	4.6	–	–	–	–	–	–	–
GRAB STRENGTH (lbs)	–	–	–	–	–	–	–	–	–	–
MD/TD (1) ASTM D 4632	–	–	–	–	–	–	–	–	–	–
TRAPEZOIDAL TEAR STRENGTH	–	–	–	–	–	–	–	–	–	–
(lbs) MD/TD (1) ASTM D 4533	–	–	–	–	–	–	–	–	–	–
BURST STRENGTH (psi) ASTM D 3786	–	–	–	–	–	–	–	–	–	–
PUNCTURE STRENGTH (lbs) ASTM D 4833	100.1	98.7	80.3	–	–	–	–	–	–	–
APPARENT OPENING SIZE (mm)	0.174	0.212	.212	–	–	–	–	–	–	–
(U.S. SIEVE NO.) ASTM D 4751	80	70	70	–	–	–	–	–	–	–
PERMITTIVITY (sec-1)	–	–	–	–	–	–	–	–	–	–
PERMEABILITY (cm/sec) (2) ASTM D 4491	–	–	–	–	–	–	–	–	–	–

(1) MD/TD corresponds to Machine Direction / Transverse Direction.
(2) Permeability calculated by multiplying measured thickness by permittivity.

AUGUST 1990 907-1086

GEOTEXTILE TEST RESULTS

PROJECT NUMBER: 907-1086
PROJECT NAME: GAI/893-6255.1/MASS.
ROLL DESIGNATION: 4

	THICKNESS (mils)	APPARENT OPENING SIZE (mm)	PERMITTIVITY (sec-1)	MASS PER UNIT AREA (oz/sq yd)
1.	–	0.180	–	4.39
2.	–	0.180	–	4.19
3.	–	0.180	–	4.09
4.	–	0.180	–	3.77
5.	–	0.150		3.63
6.	–		AVG 0.00	4.15
7.	–	AVG 0.174		3.89
8.	–		PERMEABILITY	3.64
9.	–	EQUIVALENT	(cm/sec)	4.46
10.	–	SIEVE SIZE		4.20
			0.00	
AVG	0.0	80		AVG 4.0

	GRAB STRENGTH (pounds) MD	GRAB STRENGTH (pounds) TD	TRAPEZOIDAL TEAR (pounds) MD	TRAPEZOIDAL TEAR (pounds) TD	BURST STRENGTH (lb/sq in)	PUNCTURE STRENGTH (pounds)
1.	–	–	–	–	–	111.3
2.	–	–	–	–	–	104.3
3.	–	–	–	–	–	99.2
4.	–	–	–	–	–	109.4
5.	–	–	–	–	–	96.7
6.	–	–	–	–	–	105.7
7.	–	–	–	–	–	90.1
8.	–	–	–	–	–	63.3
9.	–	–	–	–	–	120.8
10.	–	–	–	–	–	100.6
AVG	0.0	0.0	0.0	0.0	0	100.1

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GEOTEXTILE TEST RESULTS

PROJECT NUMBER: 907-1086
PROJECT NAME: GAI/893-6255.1/MASS.
ROLL DESIGNATION: 1114

	THICKNESS (mils)	APPARENT OPENING SIZE (mm)	PERMITTIVITY (sec-1)	MASS PER UNIT AREA (oz/sq yd)
1.	-	0.212	-	4.98
2.	-	0.212	-	4.79
3.	-	0.212	-	4.74
4.	-	0.212	-	5.06
5.	-	0.212		4.97
6.	-		AVG 0.00	5.07
7.	-	AVG 0.212		5.09
8.	-		PERMEABILITY	5.02
9.	-	EQUIVALENT	(cm/sec)	5.23
10.	-	SIEVE SIZE		5.33
			0.00	
AVG	0.0	70		AVG 5.0

	GRAB STRENGTH (pounds) MD	GRAB STRENGTH (pounds) TD	TRAPEZOIDAL TEAR (pounds) MD	TRAPEZOIDAL TEAR (pounds) TD	BURST STRENGTH (lb/sq in)	PUNCTURE STRENGTH (pounds)
1.	-	-	-	-	-	99.1
2.	-	-	-	-	-	96.7
3.	-	-	-	-	-	106.6
4.	-	-	-	-	-	116.2
5.	-	-	-	-	-	91.9
6.	-	-	-	-	-	90.2
7.	-	-	-	-	-	100.0
8.	-	-	-	-	-	96.1
9.	-	-	-	-	-	94.8
10.	-	-	-	-	-	95.8
AVG	0.0	0.0	0.0	0.0	0	98.7

AUGUST 1990 907-1086

GEOTEXTILE TEST RESULTS

PROJECT NUMBER: 907-1086
PROJECT NAME: GAI/893-6255.1/MASS.
ROLL DESIGNATION: 5

	THICKNESS (mils)		APPARENT OPENING SIZE (mm)		PERMITTIVITY (sec-1)		MASS PER UNIT AREA (oz/sq yd)
1.	-	1.	0.212	1.	-	1.	4.50
2.	-	2.	0.212	2.	-	2.	4.20
3.	-	3.	0.212	3.	-	3.	4.82
4.	-	4.	0.212	4.	-	4.	5.10
5.	-	5.	0.212			5.	4.82
6.	-			AVG	0.00	6.	4.79
7.	-	AVG	0.212			7.	3.91
8.	-				PERMEABILITY	8.	4.72
9.	-		EQUIVALENT		(cm/sec)	9.	5.01
10.	-		SIEVE SIZE			10.	4.45
					0.00		
AVG	0.0		70			AVG	4.6

	GRAB STRENGTH (pounds)		TRAPEZOIDAL TEAR (pounds)		BURST STRENGTH (lb/sq in)	PUNCTURE STRENGTH (pounds)
	MD	TD	MD	TD		
1.	-	-	-	-	-	82.3
2.	-	-	-	-	-	73.5
3.	-	-	-	-	-	74.6
4.	-	-	-	-	-	89.6
5.	-	-	-	-	-	95.5
6.	-	-	-	-	-	88.7
7.	-	-	-	-	-	83.8
8.	-	-	-	-	-	61.9
9.	-	-	-	-	-	75.6
10.	-	-	-	-	-	77.2
AVG	0.0	0.0	0.0	0.0	0	80.3

One of the most important properties for a gas collection layer is its absolute permeability (generally expressed in cm^2), that depends exclusively on the properties of the porous media and measures the flow capacity of any fluid through that media. When applied to a specific fluid, a coefficient of permeability (generally expressed in cm/sec) is defined, which also depends on the fluid properties. In the case of liquid fluids, the coefficient of permeability is generally called hydraulic conductivity. Hydraulic conductivity values determined for one fluid allow the hydraulic conductivity for any other fluid to be calculated.

For the borrow areas potentially usable for the gas collection layer in this project, hydraulic conductivity tests have been conducted on samples using distilled water, as an indirect measurement of their flow capacity, and from which hydraulic conductivity values could be determined for other fluids during the design stage. Since no specification of absolute permeability or hydraulic conductivity has been given in any of the governing documents, a hydraulic conductivity of 1.0×10^{-3} cm/sec is proposed as the minimum required for this layer.

As stated in the RDAP, the function of the bedding layer is to prevent clogging of the underlying gas collection system and provide a stable base for overlying layers. Since a geomembrane overlies the bedding layer, its function to prevent clogging is redundant. Also, the load from overlying layers is minimal and the gas collection system could also function as the bedding layer. Therefore, the need for a bedding layer will be re-evaluated as part of the design.

The property of importance for the bedding layer is the gradation and texture of the particles. A coarse and angular bedding layer may abrade and imbed into the overlying geomembrane, compromising its integrity. Also, a bedding layer that has a finer particle size distribution than the gas collection layer may migrate downward and clog the gas collection layer. As suggested in the Remedial Design Work Plan (p. 23) it may be advantageous to use a geotextile directly on top of the bedding layer to provide a cushion and clean working surface for the placement of the geomembrane. If the bedding layer contains finer particles than the underlying gravel, the use of a geotextile between the bedding layer and the gas collection layer would prevent particle migration downward.

A geomembrane having a minimal thickness of 40 mil is required by the RDAP to be placed on top of the bedding layer. The function of the geomembrane is to establish impermeability to prevent the migration of gases to the air and percolation of water into the East Hide Pile. No material type is specified. The choice for a geomembrane is basically related to its durability, strength, and constructability. The durability of a geomembrane is related to its chemical, physical, and mechanical properties. The mechanical properties are related, in part, to the sheet thickness. Strength properties and survivability are increased with a thicker sheet.

High density polyethylene (HDPE) is widely used for landfill liners and closures, because it is more resistant to most chemical substances than other geomembrane polymers (Reference 8). HDPE is also a low cost material relative to other liner options.

Considering the advantages discussed above, as well as Golder's experience, HDPE is tentatively recommended as the impermeable layer component. There are various properties of importance for HDPE including thickness, strength, and puncture resistance. The minimum standards for HDPE flexible membrane liner are outlined in the National Sanitation Foundation (NSF) Standard Number 54 (Reference 9). Typically thicknesses for HDPE liners are 40 or 60 mils. Generally, field testing allows for a variance in thickness of 10 percent. The minimum strength requirements for 40 and 60 mil HDPE are listed below:

	40 mil	60 mil
Tensile Strength at Yield (lb/in. width)	70	120
Tensile Strength at Break (lb/in. width)	120	180
Elongation at Yield (Percent)	10	10
Elongation at Break (Percent)	500	500

The NSF does not give minimum requirements for puncture resistance. Typically landfill liner specifications for geomembranes require puncture resistance of 40 and 60 pounds for 40 and 60 mil HDPE, respectively.

2.3.2 Middle Drainage Layer

A drainage layer is required to be placed on top of the geomembrane. The RDAP specifies in Attachment A that the middle drainage layer shall be:

"(1) of a thickness designed to accommodate the expected amount of settling and the maximum volume of water that could enter the drainage layer, but in any event no less than 6 (six) inches;

(2) consisting of a material whose permeability exceeds 1×10^{-3} cm/sec., i.e., a sand in the SW or SP range of the Unified Soil Classification System or coarser material;

(3) designed and constructed with a bottom slope of at least 2 percent; and,

(4) *designed and constructed to prevent clogging.*"

The function of the drainage layer is to transmit the maximum volume of water that could enter the system to prevent ponding effects. The significant properties of the drainage layer are gradation and hydraulic conductivity as specified by the RDAP. The gradation of the drainage layer is important since it is related to permeability. The angularity is also important for the survivability of the underlying geomembrane, to minimize abrasions and scratches during installation.

The thickness of the drainage layer will depend on design calculations. The RDAP specifies a thickness of no less than 6 inches. It must be considered that the thickness of cover over the geomembrane should be, at a minimum, equal to the depth of frost penetration to allow for a functioning drainage layer throughout the year. The ACDR indicated that the average frost depth will not penetrate a 16 inch cover.

2.3.3 Vegetated Top Layer

A vegetated layer is required to be placed above the drainage layer. The RDAP in Attachment A specifies the vegetated top layer shall be:

"(1) of a thickness designed to accommodate the maximum depth of root penetration and the rate of anticipated soil loss, but in any event no less than 6 inches;

(2) capable of supporting vegetation that minimizes erosion and minimizes continued maintenance;

(3) planted with a persistent species with roots that will not penetrate beyond the vegetative and drainage layers;

(4) designed and constructed with a top slope of between three (3) percent and five (5) percent after settling and subsidence or, if designed and constructed with a slope of greater than five (5) percent, an expected soil loss of less than two (2) tons/acre/year using the USDA universal soil loss equation; and,

(5) designed and constructed with a surface drainage system capable of conducting effective run-off across the cap."

The functions and requirements of the upper vegetated layer are well outlined above. The properties relative to these functions include gradation, organic content and soil fertility. These properties are important to properly design a consistent seed and fertilizer program for rapid and persistent vegetative growth.

2.3.4 Quantity Estimate

Quantity estimates for the various impermeable cap components are given in the Pre-Design Work Plan (p. 48) and are discussed below. The estimates are based on a cap size of approximately 3.8 acres and the minimum thicknesses specified in the RDAP. The quantities are subject to change based on the final cap design and dimensions.

The quantity of gas collection gravel required will be on the order of 6,000 cubic yards, based on a 12-inch thick layer.

The amount of geomembrane required is 3.8 acres or about 18,400 square yards. This estimate does not account for overlap and waste, that can be calculated when the individual roll dimensions are available.

The amount of material for the middle drainage layer is estimated to be 3,000 cubic yards, based on the minimum thickness of 6 inches.

The total volume required for the vegetated top layer is approximately 6,000 cubic yards, based on a thickness of 12 inches over the 3.8 acre area. This thickness is consistent with that given in the ACDR as the upper bound for supporting vegetation and root penetration.

As discussed before, a bedding layer may not be required. In case it is included in the design, the required volume would be 3,000 cubic yards, based on a minimum thickness of 6 inches. Additionally, one or two geotextile layers may be included over the 3.8 acre area (18,400 square yards per layer).

APPENDIX D

Pre-Design Work Plan
Tables 6 and 16

TABLE 6

Laboratory Testing

Task S-3, Identify Sources of Cap Materials

Borrow Material	Number of Samples
Topsoil	5
Fill	4
Drainage	3
Gas Collection Layer	3
Laboratory Tests on Soils and Stone	
Baker Test	5
Sieve Gradation	15
Atterberg Limits	9
Organic Content	9
Soil Ph	4
Proctor (Modified)	4
Permeability	6
Consolidation	4
Strength (Triaxial CD or CU)	4
Soil Grain Specific Gravity	4
Laboratory Tests on Geosynthetics	
Thickness	3
Strength	3
Puncture Resistance	3
Weight	3
Aperature Size	3

TABLE 16 (Cont.)
DATA QUALITY OBJECTIVE SUMMARY

MEDIA	CONSENT DECREE OBJECTIVE	DATA NEEDS	ANALYSES	NUMBER OF SAMPLES	ANALYTICAL LEVEL	ANALYTICAL METHOD	RATIONALE
Soil	b)The installation of the monitoring network shall be designed to provide a ground water quality ... data base to allow post-closure monitoring in areas of the east and West Hide Piles adjacent to the wetlands. (Task S-2)	Groundwater quality adjacent to East and West Hide Piles	TCL/TAL	2	IV	CLP-RAS	Two wells located between the hide piles and the wetlands will be used to assess shallow groundwater quality and provide monitoring points for O&M monitoring
	Evaluate sources of cap materials for their ability to meet technical design requirements as specified in the Consent Decree. (Task S-3)	Permeable cover fill material	Grain size distribution	4	N/A	ASTM-D422	Samples from each potential borrow source will be tested to determine material gradation, USC classification, consolidation, compaction, organic content, acidity and grain specific gravity for suitability as fill
			Atterberg limit	4	N/A	ASTM-D4318	
			Shear strength	4	N/A	COE EM 1110-2-1906	
			Consolidation	4	N/A	ASTM-D2435	
			Proctor density	4	N/A	ASTM-D1557	
			Organic content	4	N/A	ASTM-D2974	
			Soil pH	4	N/A	ASTM-G51	
			Soil Grain Specific Gravity	4	N/A	ASTM-D854	
		East Hide Pile Cover topsoil	Grain size distribution	5	N/A	ASTM-D422	Samples from each potential topsoil borrow source will be tested to determine material gradation for USDA and UCS classification and to determine the nutrients required to establish vegetation.
			Atterberg limit	5	N/A	ASTM-D4318	
			Organic content	5	N/A	ASTM-D2974	
			Soil fertility	5	N/A	Baker Test	

TABLE 16 (Cont.)
DATA QUALITY OBJECTIVE SUMMARY

MEDIA	CONSENT DECREE OBJECTIVE	DATA NEEDS	ANALYSES	NUMBER OF SAMPLES	ANALYTICAL LEVEL	ANALYTICAL METHOD	RATIONALE
Soil		East Hide Pile cover drainage layer sand	Grain size distribution	3	N/A	ASTM-D422	Samples from each potential borrow source will be tested to determine USDA classification and flow capacity.
			Permeability	3	N/A	COE EM 1110-2-1906	
		East Hide Pile cover gas collection gravel	Grain size distribution	3	N/A	ASTM-D422	Samples from each potential borrow source will be tested to determine USDA classification and flow capacity.
			Permeability	3	N/A	COE EM 1110-2-1906	
		Permeable cover filter fabric	Aperture Size	3	N/A	ASTM-D4751	To ensure compliance with design specification for weight and aperture
			Weight	3	N/A	ASTM-D3776	
		East Hide Pile cover Flexible Memebrane Liner	Strength	3	N/A	ASTM-D4632	To insure that the FML will meet the design specifications against tearing, puncture or degradation.
			Puncture resistance	3	N/A	ASTM-D4833	
			Thickness	3	N/A	ASTM-D1777	
			Environmental compatibility	3	N/A	Literature Review	
	An additional task has been added to perform a preliminary foundation assessment for potential treatment plant sites (Task S-4)	Bearing capacity	Standard penetration tests	48	N/A	ASTM-1586	Soils investigation is required to locate potentially suitable sites for construction of water and gas treatment facilities.
			Grain size distribution	15	N/A	ASTM-D422	
			Atterberg limit	15	N/A	ASTM-D4318	
			Shear strength	6	N/A	COE EM 1110-2-1906	
			Consolidation	4	N/A	ASTM-D2974	